BLEEDING VESSELS IN LIFE THREATENING HEMOPTYSIS: COMPARISON OF 64 DETECTOR ROW CT ANGIOGRAPHY WITH CONVENTIONAL ANGIOGRAPHY PRIOR TO ENDOVASCULAR MANAGEMENT

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INDIA

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CERTIFICATE

This is to certify that **Dr.Iyappan Ponnuswamy** has been a post graduate student during the period April 2007 to March 2010 at Barnard Institute of Radiology, Madras Medical College, Government General Hospital, Chennai.

This Dissertation titled **"Bleeding Vessels in Life Threatening Hemoptysis: Comparison of 64 Detector Row CT Angiography with Conventional Angiography Prior to Endovascular Management"** is a bonafide work done by him during the study period and is being submitted to the Tamilnadu Dr. M.G.R. Medical University in partial fulfillment of the M.D. Branch VIII Radiodiagnosis Examination.

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INTRODUCTION

Hemoptysis is defined as bleeding that originates from the lower respiratory tract. (1) In developing countries, the majority of cases are due to tuberculosis. (2) Massive hemoptysis is a major clinical and surgical problem with a mortality of 80%, which is most often related to asphyxiation. (3,4) Conservative management of massive hemoptysis carries a mortality rate of 50%–100% (5) and the mortality is up to 35% even in patients undergoing operation. (6) Because of poor pulmonary reserve and other medical comorbid conditions, most patients with massive hemoptysis are not ideal surgical candidates. (4,5) Therapeutic bronchial artery embolization is a good treatment adjunct to control bronchial bleeding and reduces the need for high-risk emergency lung resections. (7)

It has become an established procedure in the management of massive and recurrent hemoptysis; its use was first reported in 1973 by Remy et al. (8) It is a useful therapy to control both acute and chronic hemoptysis (9) and is an effective method for management of massive hemoptysis in developing countries and has a low complication rate. (10,11) BAE may help to avoid surgery in patients who are not good surgical candidates. Should hemoptysis recur in these patients, repeat embolization can be performed safely. (9) Surgery remains the procedure of choice in the treatment of massive hemoptysis caused by specific conditions, such

as hydatid cyst, thoracic vascular injury, bronchial adenoma, and aspergilloma that is resistant to other therapies. (12) Even in surgical candidates, BAE is effective in preparing the patient for elective rather than high-risk emergency surgery. (7)

Various nonbronchial systemic arteries, as well as pulmonary arteries, may also contribute to hemoptysis, and their implication is dependent on the underlying pathologic condition. (13-18) Nonbronchial systemic collateral vessels must be particularly suspected when there is evidence of coexistent pleural disease. (11,19) Recognition and occlusion of nonbronchial systemic collaterals providing blood to hypervascular pulmonary lesions is essential for successful percutaneous embolotherapy of hemoptysis. (2,17-20)

Prior to embolization, the interventional radiologist needs to be aware of the side of the bronchial artery bleeding, and the most likely source of bleeding has to be identified to determine which vessel(s) is to be occluded. Since the bronchial circulation is the most frequent source of hemoptysis, embolization of bronchial arteries is usually the favored therapeutic option to stop the bleeding. (11,21) Recent important technologic advances in CT, particularly the development of multi– detector row CT, have introduced a comprehensive, noninvasive method of evaluating the entire thorax, allowing detailed assessment of the mediastinum and lung parenchyma. (11,21)

Multi–detector row helical CT angiography can also help in the planning of a focused and efficient nonbronchial systemic artery embolization. It provides a precise road map for the interventional radiologist in performing an endovascular treatment for hemoptysis. The availability of this information before the patient arrives in the angiographic suite is expected to help reduce the examination time by facilitating attempts at direct selective catheterization of the arteries to be occluded. (21)

AIM OF THE STUDY

The purpose of the present study is to retrospectively evaluate the depiction of bronchial and nonbronchial systemic arteries with multi–detector row helical CT compared with conventional angiography in patients undergoing endovascular treatment of hemoptysis.

REVIEW OF LITERATURE

1. LIFE THREATENING HEMOPTYSIS:

Massive hemoptysis is a major clinical and surgical problem with a mortality of 80%, which is most often related to asphyxiation. (3) There are various definitions for massive hemoptysis in literature. It has been described as the expectoration of an amount of blood ranging from 50 mL to more than 1,000 mL over a period of 24 hours, and the most widely used criterion is the production of 300–600 mL per day. (4,5,6,7,12,22,23) However, depending on the ability of the patient to maintain a patent airway, a lifethreatening condition may be caused by a rather small amount of hemorrhage. Thus, a more functional definition of "massive" as an amount sufficient to cause a life-threatening condition should be used in deciding whether to undertake interventional management . (12,24,25) Asphyxiation and less commonly exsanguination are the usual causes of death.(27)

Any assessment of the severity of hemoptysis must take into account the patient's cardiorespiratory status, bleeding activity, the possibility of "internalized" (eg, intrapleural, intrapericardial, or intracavitary) bleeding, and the risk of recurrent bleeding. In particular, the recognition of "sentinel bleeding" heralding imminent major hemorrhage is of critical importance but is often difficult on the basis of clinical findings alone. (28,29) The chronicity of the disease is an

important aspect in selecting a patient for radiological intervention. It is in this clinical setting that bronchial artery hypertrophy occurs, facilitating transcatheter therapy. Without hypertrophy, bronchial artery embolization is less likely to be of benefit.

Chronic inflammatory lung disease is the predominant cause of severe hemoptysis. (2,10,26) In the non-Western world, pulmonary tuberculosis is the most common underlying cause of massive hemoptysis. Massive hemoptysis in patients with tuberculosis is reported usually in association with cavitary disease or aspergiloma. However, there are case reports of sputum positive tuberculosis with massive recurrent tuberculosis without evidence of any cavitary disease. (37) In patients with tuberculosis, hemoptysis is a major cause of death, even in the era of effective antituberculous therapy. (38) Those with mycetoma suffer the highest recurrence of bleeding even after embolization. (39) Bronchogenic carcinoma and chronic inflammatory lung diseases due to bronchiectasis, cystic fibrosis, or aspergillosis are the more prevalent causes of hemoptysis in Western countries. (4,5,12,30) Other causes of hemoptysis include pulmonary malignancy, arterioarterial shunts, pulmonary trauma, pulmonary arteriovenous malformation, bronchial artery aneurysm, pulmonary pseudosequestration, dieulafoy disease, congenital heart disease, after Glenn and Blalock anastomoses, interstitial disease, pulmonary hypertension and pulmonary embolism. (9,17,23,31-36,40-44,47,48) A

pulmonary arterial source should also be considered when bleeding continues after technically successful bronchial artery and nonbronchial systemic arterial embolization. The pulmonary arteries may also be the source of hemorrhage in cases of direct invasion by neoplastic disease or by necrotizing inflammatory disorders such as tuberculosis (15,40) and can be treated by embolization (45,46)

Cryptogenic hemoptysis (hemoptysis for which no cause has yet been identified) is a diagnosis of exclusion and has a reported prevalence of approximately 3%–42%. (50-53) It occurs most often in patients who smoke, and its importance lies in the reported statistic that 6% of such patients will present with unresectable lung carcinoma within the next 3 years. (52,54)

2. RELEVANT ANATOMY

The lungs are supplied by a dual arterial vascular system composed of (a) the pulmonary arteries, which account for 99% of the arterial blood supply to the lungs and take part in gas exchange; and (b) the bronchial arteries, which are responsible for providing nourishment to the supporting structures of the airways and of the pulmonary arteries themselves (vasa vasorum) but do not normally take part in gas exchange. (55) The bronchial vasculature feeding the intrapulmonary airways is situated close to the pulmonary arteries at the level of the vasa vasorum, and histologically the two systems are connected by anastomoses between the

systemic and pulmonary capillaries. (56) Bronchial artery branches supply the vasa vasorum of the aorta, pulmonary artery and vein as well as the diaphragmatic and mediastinal portions of the visceral pleural, the middle third of the esophagus, trachea, extra- and intrapulmonary airways, bronchovascular bundles, nerves, supporting structures, regional lymph nodes, and lymph nodes. Most of the venous return occurs through the pulmonary veins by way of bronchial pulmonary anastomoses. (55,57)

There is an extensive potential anastomotic network between the bronchial arteries and other structures in the mediastinum, spine, head, and neck. These bronchial pulmonary arterial anastomoses may become prominent in the abnormal lung, reflecting either chronic inflammation or pulmonary hypertension. (17,58) This communication between the bronchial and pulmonary arteries contributes to a normal right-to-left shunt that accounts for 5% of cardiac output. (55)

The bronchial arteries have variable anatomy in terms of origin, branching pattern, and course. (4, 59) In over 70% of the general population, the bronchial arteries arise from the descending thoracic aorta, most commonly between the levels of T5 and T6. There are normally one or two bronchial arteries supplying each lung, arising either independently or from a common trunk. (3, 60)

On the right side, an intercostobronchial trunk usually exists, arising from the right posteromedial aspect of the aorta and coursing cranially before giving rise

to one or more posterior intercostal arteries and a right bronchial arterial component. This component turns sharply in the caudal direction to the level of the right main bronchus, where it ramifies in the lung parenchyma parallel to the bronchus and more distal airways. The left bronchial artery usually arises from the anterior aspect of the descending thoracic aorta, either singly (30.5% of cases) or as a common trunk with a second right bronchial artery (25%), before coursing toward the left hilum and perhaps through the aortopulmonary window. (21, 61)
In 70% of cases, there are two left bronchial arteries in addition to the right intercostobronchial trunk. (60) Bronchial arteries that arise in the expected location from the descending thoracic aorta between the levels of T5 and T6 are called orthotopic bronchial arteries. Anomalous bronchial arteries, defined as bronchial arteries that originate outside the T5 through T6 range, are found in 8.3%–21% of cases of hemoptysis. (43, 62)

The bronchial arteries have highly tortuous but predictable trajectories that can easily be analyzed with a thorough knowledge of bronchial arterial anatomy. Cauldwell, in 1948, described four common variations: (Fig 1) type 1—two left and single right bronchial arteries (41 percent); type 2—single bronchial arteries bilaterally (21 percent); type 3—two left and two right bronchial arteries arising separately or in various combinations (21 percent); and type 4—single left and two right bronchial arteries (10 percent). (60) In 1985, Uflacker and colleagues

classified bronchial artery variations into ten types (Fig 2) and reported common bronchial trunks in 43% of patients (3) The four most common types in Uflacker's study can be seen in Figure 3. The bronchial arteries can drain into the Pulmonary artery, Pulmonary vein or into the bronchial vein. (57) In adults, normal bronchial arteries measure less than 1.5 mm in diameter at their origin and 0.5 mm at their point of entry into a bronchopulmonary segment. (55)

Anomalous bronchial arteries, defined as bronchial arteries that originate outside the T5 through T6 range, are found in 8.3%–21% of cases of hemoptysis. (21, 60,62) They are easily overlooked during bronchial artery embolization, even when complemented with arch aortography. (63) As many as 20 percent of bronchial arteries have anomalous origins from sites other than the aorta, and approximately 10 percent originate from the concave or convex surfaces of the aortic arch. Other aberrant origins of the bronchial arteries include the subclavian, thyrocervical, internal mammary, innominate, pericardiophrenic, superior intercostal, abdominal aorta, and inferior phrenic arteries. (11, 21, 60, 62,64-66)

Recognition and occlusion of nonbronchial systemic collaterals providing blood to hypervascular pulmonary lesions is essential for successful percutaneous embolotherapy of hemoptysis. (17, 18). These arteries provide systemic collateral vessels that reach the lung parenchyma via the inferior pulmonary ligaments (in the case of the inferior phrenic arteries) or transpleural adhesions (in the case of

branches from the intercostal and supraaortic arteries) and that form anastomoses with the pulmonary arterial circulation in regions of inflammation or neoplasia. (9,11,17,63,67,68) These nonbronchial systemic vessels must be suspected when there is pleural disease adjacent to the pulmonary parenchymal lesion. (19, 69)

A pulmonary arterial source should also be considered when bleeding continues after technically successful bronchial artery and nonbronchial systemic arterial embolization. (15) Peripheral pulmonary artery pseudoaneurysms occur in up to 11% of patients undergoing bronchial angiography for hemoptysis. (45)

In disease entities that cause diminished pulmonary arterial blood flow such as cyanotic congenital heart disease, chronic thromboembolic disease, and vasculitides such as Takayasu arteritis, shunting can occur from coronary arteries to pulmonary arteries via the bronchial arteries. (70,71) Coronary-to bronchial arterial anastomoses normally arise from the atrial branches of both coronary arteries. Such shunting may be involved in the “pulmonary steal” syndrome that manifests in some patients as classic angina-like symptoms in the presence of angiographically normal coronary arteries. (72)

Coronary-to-bronchial artery anastomoses are most often identified in the region of the retrocardiac “bare areas” of the heart, where the relatively wide pericardial reflections permit the development of communications between the coronary and extracoronary arteries. (73) Conversely, in certain situations atherosclerotic

coronary artery disease can promote the development of bronchial-to-coronary arterial shunting.(74)

The two kinds of spinal arteries which may be seen at bronchial and intercostal angiography during BAE are the radicular arteries and anterior medullary arteries. Dorsal and ventral radicular arteries are small vessels that arise from segmental spinal arteries and supply the dorsal and ventral roots. (75) The anterior spinal artery originates from branches of the intracranial segments of the vertebral arteries and receives supply from anterior radiculomedullary branches of intercostal and lumbar arteries along its length. As many as six to eight contributing branches to the anterior spinal artery may exist, and each has a characteristic course resembling a hairpin loop. The largest anterior medullary branch (the artery of Adamkiewicz) has a variable origin from the T5 to L5 level but is most commonly found at the T8 to L1 level. (75-77) The right superior intercostal artery and right bronchial artery may share a common trunk and supply a branch to the anterior spinal artery . Left bronchial arteries rarely supply the anterior spinal artery. The posterior portion of the cord is supplied by a pair of posterior spinal arteries that course along the posterolateral surface of the spinal cord. These vessels are fed by posterior radicular arteries arising from intercostal and lumbar arteries and are much shorter and smaller than the anterior radiculomedullary arteries. (76)

3. PATHOPHYSIOLOGY OF HEMOPTYSIS

Chronic inflammatory disorders such as bronchiectasis, chronic bronchitis, and chronic necrotizing infections (in particular, tuberculosis and mycotic lung disease) are associated with the release of angiogenetic growth factors such as vascular endothelial growth factor and angiopoietin 1, leading to neovascularization and vascular remodeling as well as an increase in the collateral supply from nearby systemic vessels. Such newly formed collateral vessels are usually fragile and “leaky” and prone to rupture. (78,79)

In certain situations, the thin-walled capillary communications between the high-pressure systemic bronchial arterial system and the lowerpressure pulmonary arterial system can vasodilate and enlarge. Conditions causing reduced pulmonary arterial perfusion such as chronic thromboembolic disease and vasculitic disorders, in which there is a reduction in pulmonary arterial supply distal to the emboli, can lead to a gradual increase in the bronchial arterial contribution), thereby increasing the importance of bronchialto- pulmonary artery anastomoses in regions of the lung that are deprived of their pulmonary arterial blood flow. (55,70,80-83)

The anastomotic vessels, which are subjected to increased systemic arterial pressure, are often thin walled and prone to rupture into the alveoli or bronchial

airways, giving rise to hemoptysis. Chronic inflammation can also lead to an increase in systemic arterial blood flow. (17,84)

In 95% of cases of hemoptysis, the systemic arterial system is the origin of the bleeding. (11,85) In a minority of cases (5%), massive hemoptysis may originate with the aorta (eg, aortobronchial fistula, ruptured aortic aneurysm) or the systemic arterial supply to the lungs. (86-88)

4. EVALUATION OF HEMOPTYSIS

The current standing of the various imaging modalities for evaluation of life threatening hemoptysis is listed below:

A) CHEST RADIOGRAPH

Conventional radiography is a basic study and is readily available even under emergency conditions. It may be helpful in diagnosing and localizing pneumonia, acute or chronic pulmonary tuberculosis, bronchogenic cancer, or lung abscess. (89) However, radiographic findings are normal or nonlocalizing in 17%–81% of patients with hemoptysis.(24,50,89-92) Chest radiograph may correlate well with angiographic findings if there is one lobar lesion, but multiple lobar lesions showed no correlation between the two modalities.(93) Pleural thickening

can be noted at chest radiography which negatively influences the long-term success rate of BAE. (94)

B) BRONCHOSCOPY

Bronchoscopy has long been considered by chest clinicians to be the primary method for diagnosis and localization of hemoptysis. (95,96) The diagnostic accuracy of FOB in patients with hemoptysis and normal chest radiographs is low, ranging from 0% to 31% . (50,89,91,97,98) Bronchoscopy, performed with either a rigid or a flexible fiberoptic endoscope, is useful in diagnosing active hemorrhage and has been stated to be useful in controlling the airway in patients with catastrophic hemorrhage. (96,99) FOB has some disadvantages in the diagnosis and localization of massive, active hemoptysis. It is difficult to localize the bleeding site with FOB in patients with massive hemoptysis because of excessive blood in the bronchi. (24) Furthermore, irritation of the bronchial mucosa caused by lavage or by the endoscope itself can lead to recurrent bleeding. (24,100)

C) SINGLE DETECTOR CT

Possible underlying causes of hemoptysis that are identifiable on axial CT scans obtained with lung parenchymal window settings include bronchiectasis, lung carcinoma, acute and chronic lung infections (in particular, tuberculosis and

aspergillosis), and cardiogenic pulmonary edema. In patients with extensive bilateral disease or equivalent findings, the site of hemorrhage can usually be localized on the basis of the presence of liquified material in segmental and lobar bronchi and hazy consolidation or ground-glass infiltrates in the lung parenchyma, findings that represent intraalveolar hemorrhage. The accurate localization of the site of bleeding is important both for possible future lung resection and prior to endovascular therapy, for which identification of the specific vessels that require embolization is necessary. The consequences of hemorrhage into the airways and lung parenchyma may also mask subtle underlying disease. (49,50,101)

CT findings can suggest a specific diagnosis in 50% of patients in whom FOB findings are nondiagnostic and in 39%–88% of patients in whom chest radiographs are nondiagnostic. (89,90,91,101) CT can also help localize the site of bleeding in 63%–100% of patients with hemoptysis, a rate that is higher than that for FOB. (24,92) It has been stated that CT and FOB are not competitive but complementary tools for assessing patients with hemoptysis, and indeed, the combined use of FOB and CT does yield the best results in evaluating hemoptysis. (92) However, many researchers are currently suggesting that CT should be performed prior to bronchoscopy in all patients with hemoptysis. (12,89-91)

Published studies on the efficacy of single– detector row spiral CT have already demonstrated the capacity of this imaging technique to help predict the site

of bleeding as accurately as bronchoscopy and to help detect underlying disease with high sensitivity. (50,100) More recently, Yoon et al have evaluated the accuracy of single– detector row helical CT in helping to predict the presence of a nonbronchial systemic arterial supply in patients with massive hemoptysis, but they did not evaluate the clinical effect of CT findings in therapeutic decisions. (20)

D) MULTIDETECTOR CT

Urgent evaluation with thoracic CT angiography can help accurately identify the source and predisposing causes of hemoptysis and the effects of hemorrhage on the lungs. (49) Multi–detector row CT provides extended volume coverage with higher image resolution and even greater scanning speed. (103,104)

The aims of multi– detector row CT in the evaluation of hemoptysis are threefold: (a) to depict underlying disease with high sensitivity by means of detailed images of the lung parenchyma and mediastinum, and in particular to help detect early carcinoma; (b) to help assess the consequences of hemorrhage into the alveoli and airways, which may cause immediate clinical concerns as well as mask subtle underlying abnormalities; and (c) to provide a detailed “road map”of the thoracic vasculature by means of two-dimensional (2D) maximum-intensity-projection (MIP) reformatted images and three-dimensional (3D) reconstructed

images. Such road maps are of great use to both the interventional radiologist anticipating arterial embolization and the thoracic surgeon contemplating surgery. (49) Multi–detector row helical CT has the ability to scan the entire thorax with a thin collimation, thus enabling the identification of bronchial arteries not only of orthotopic origin but also of ectopic origin.

i) ASSESSMENT OF LUNG PARENCHYMA AND PLEURA

MDCT can accurately evaluate the lung parenchymal diseases which might be the cause for hemoptysis. Since it is fast, there is no need for breath holding also. Various diseases which can be detected on MDCT are cavitary disease, bronchiectasis, aspergilloma, consolidation, interstitial disease and fibrosis. Pleural thickening of more than 3 mm and tortuous enhancing vascular structures within hypertrophic extrapleural fat seen at contrast enhanced CT are signs of nonbronchial systemic arterial supply in patients with massive hemoptysis. (11,20) In the presence of pleural thickening, nonbronchial systemic feeder vessels that originate from various arteries (eg, intercostals artery, branches of the subclavian and axillary arteries, internal mammary artery, inferior phrenic artery may develop along the pleural surface and become enlarged as a result of the inflammatory process. (4,17,39,67,69)

ii) CT OF BRONCHIAL ARTERIES

The site of origin and distribution of bronchial arteries are analyzed on transverse CT scans, maximum intensity projections and volume-rendered images. (105) CT interpretation focused on the evaluation of bronchial arteries ipsilateral to the side of bleeding is done by recording the following parameters: (a) the site of the ostium of the bronchial artery (or arteries), which is coded as orthotopic when the artery was originating from the descending aorta between the levels of the T5 and T6 vertebrae or ectopic when identified at a level of the descending aorta other than the expected origin (i.e., outside levels T5- T6), such as the level of the aortic arch or from any aortic collateral vessel; (b) the origin of orthotopic bronchial arteries, which is further analyzed and included a systematic analysis of its location on the wall of the descending aorta (i.e., posterior, medial, anterior, or lateral) and its position relative to the tracheal carina; (c) the bronchial artery diameter, which is coded as enlarged when greater than 1.5 mm and (d) the total number of bronchial arteries per side. (21,80,106,107)

In adults, normal bronchial arteries measure less than 1.5 mm in diameter at their origin and 0.5 mm at their point of entry into a bronchopulmonary segment. (55) The primary locations of enlarged bronchial arteries at CT are the retro esophageal area, retro- tracheal area, retro bronchial area, posterior wall of the main bronchus, and aortopulmonary window. Mediastinal lymph nodes, the azygos

vein, and an enhancing esophageal wall can mimic the bronchial arteries at CT. (108) The presence of calcifications of the aortic wall does not hamper the analysis of bronchial arteries. Both the site of the origin of the bronchial artery and its hilar path can be precisely identified. Both transverse CT scans and three dimensional reconstructions are required for accurate evaluation of bronchial arteries. Although curved reformations provide complementary information for most right orthotopic bronchial arteries, left bronchial arteries are not adequately demonstrated because of their short mediastinal length. Three-dimensional images were found to be superior to transverse CT scans in depicting the ectopic origin of the bronchial arteries, which enabled the interventional radiologists to perform successful embolization after direct catheterization of the ectopic vessel in every case. (21) Bronchial arteries of anomalous origin are easily overlooked during bronchial artery embolization, even when complemented with arch aortography but are well depicted with extended thoracic CT angiography that includes the base of the neck and the upper abdomen. (63)

iii) CT OF NONBRONCHIAL SYSTEMIC ARTERIES

Multi–detector row helical CT angiography can help in the planning of a focused and efficient nonbronchial systemic artery embolization. (11,21) CT features suggestive of a nonbronchial systemic arterial supply are recorded for each hemithorax in each patient together with a specific evaluation of the pulmonary

circulation in the relevant area. For each nonbronchial artery considered in the present investigation, depiction of its ostium and recognition of its course toward the adjacent lung parenchymal zone are analyzed on transverse CT scans and three-dimensional images to determine if CT angiography has the ability in helping to evaluate this vessel. The following features were considered to be suggestive of a nonbronchial systemic arterial supply as a source of hemoptysis: (a) abnormal enlargement of one or several of the branches of the subclavian and axillary arteries, particularly the internal mammary artery and its branches, the intercostal arteries, and the inferior phrenic arteries, and (b) the enlarged nonbronchial systemic arteries seen with or without the concurrent presence of pleural thickening and pulmonary abnormalities. (21)

Two CT features were considered to be indirect predictors of a nonbronchial systemic arterial supply: (a) pleural thickness of more than 3 mm adjacent to the parenchymal lesion and (b) enhancing vascular structures within the extrapleural fat layer. In the determination of a nonbronchial systemic arterial supply, CT had a sensitivity of 80%, specificity of 84%, positive predictive value of 73%, negative predictive value of 91%, and accuracy of 84%. Sensitivity was highest for predicting the branches of subclavian and axillary arterial supply and was lowest for predicting the internal mammary arterial supply. Specificity and accuracy were highest for predicting the intercostal arterial supply.

iv) CT OF PULMONARY VESSELS

Rasmussen aneurysms, representing fragile pulmonary arterial pseudoaneurysms arising within areas of tuberculous inflammation, may be responsible for sentinel bleeding prior to catastrophic hemorrhage and can be identified on contrast-enhanced CT scans as avidly enhancing nodules located within the walls of tuberculous cavities. (109-111)

v) CT DETECTION OF SPINAL SUPPLY

At contrast-enhanced thoracic CT angiography for the evaluation of hemoptysis prior to embolization therapy, it may be possible to visualize the artery of Adamkiewicz; however, the fine caliber of this artery and the possibility of mistaking it for an anterior spinal vein make it difficult to identify with certainty. (112) The AKA commonly originates from the left side. (113) By using the CT angiographic criteria reported by Takase et al for the recognition of the Adamkiewicz artery , the anterior spinal artery is searched for as a thin enhanced vessel on the midline ventral surface of the spinal cord, with a typical hairpin curve on coronal and sagittal MIPs of the cervicothoracic region. (112) CT angiography could represent a useful complementary means to prevent spinal cord ischemia when it is performed in association with the monitoring of somatosensory evoked potentials, a technique routinely used in our clinical practice. (114.115)

E) CONVENTIONAL ANGIOGRAPHY

i) ANGIOGRAPHY TECHNIQUE

Arterial access is most commonly achieved via common femoral artery puncture by modified Seldinger's technique through which a sheath is inserted. If the patient is obese or if the iliac vessels are markedly tortuous, a long sheath is used that extends into the aorta. A variety of selected catheter curves can be used for subselective catheterization. When there is a low aortic arch or if the bronchial artery originates from the arch, a reverse-curve catheter may fail to adequately probe the aortic wall. The apex of the reverse-curve catheter will lie partially within the transverse arch, tilting the catheter and making catheterization of more proximately located bronchial arteries impossible. In these circumstances, forward-looking catheters, such as the cobra, H1H, or RC shapes, can be used successfully. In general, 5.0 or 5.5 French catheters are initially used, reserving the larger 6.5 to 7.0 French catheters for a particularly tortuous vascular system where increased steerability is required.

The bronchial artery search is begun at the T5 to T6 level. (60) In addition to the location of the ostium of orthotopic bronchial arteries on the surface of the aortic wall, the caudocranial level of origin is also analyzed. Whereas most authors describe the origins of bronchial arteries based on the level or range of thoracic

vertebrae, (60,116,117) this area of reference is wide and difficult to accurately identify at fluoroscopy. (118)

The air-filled left main stem bronchus serves as a convenient fluoroscopic landmark for this general location of bronchial artery origin. The catheter tip is initially directed laterally to anterolaterally when one is searching for the right bronchial artery or intercostobronchial trunk. A left lateral to anterolateral direction is used for left bronchial artery catheterization. Before embolization, a selective arteriogram must be performed. Bronchial arteries have characteristic branches that follow the course of the main stem bronchi toward the hila and can be easily differentiated from intercostal arteries, which have an initial cephalic course and then travel laterally along the undersurface of a rib. Coughing may be elicited during a bronchial artery injection, whereas a pure intercostal artery injection may be painful but will not initiate coughing. Nonionic contrast media should be used for all injections.

The injection volumes and rates must be sufficient to identify any spinal artery branches that may exist. The spinal artery can be identified by its characteristic cephalic course with a hairpin bend in the midline within the spinal canal. If there is some doubt concerning a midline branch on an anteroposterior film, an oblique film should be obtained to identify whether this branch does indeed enter the spinal canal. Tracheal and esophageal branches also originate from the bronchial artery

and may appear midline on anteroposterior films but do not feature the hairpin loop. When abnormal bronchial arteries are not identified, arch aortography and selective subclavian arteriography must be performed to search for anomalous bronchial arteries, nonbronchial systemic arterial supply, or both. (18,119,120)

ii) ANGIOGRAPHIC FINDINGS IN HEMOPTYSIS

The following findings are noted in cases with hemoptysis on angiography:

a) Hypervascularity

b) Bronchial artery hypertrophy more than 1.5 mm

c) Broncho pulmonary shunting

d) Dense soft tissue staining

e) Active extravasation of contrast

d) Vascular abnormalities like bronchial artery pseudoaneurysm

(9,2,10,14,16,21,40,93,121-124)

A recent study showed a poor correlation between bronchial arterial dilatation and the risk of hemorrhage. (125) and no angiographic abnormalities were found in 11% of hemoptysis patients in another study.(2) Anomalous bronchial arteries represent a potential pitfall during bronchial artery embolization. Radiologists involved in embolotherapy for hemoptysis should therefore be alerted to the possible presence of anomalous bronchial arteries, especially when significant

bronchial artery supply to areas of abnormal pulmonary parenchyma is not demonstrated at a catheter search or aortography of the descending aorta. (65)

iii) IDENTIFICATION OF NONBRONCHIAL SUPPLY

On angiographic studies, systemic vessels responsible for an abnormal collateral blood supply to the lungs in episodes of hemoptysis appear as dilated, usually tortuous arteries with associated parenchymal staining by contrast material, systemic- to-pulmonary arterial shunting, and, rarely, contrast material extravasation at the points of bleeding. (3,26,61)

More than one third have nonbronchial systemic artery contributions, indicating that a concerted search for these is mandatory. (2,17) Of particular importance is the subclavian artery and its branches (most commonly, the internal mammary artery) for upper-lobe bleeding and the inferior phrenic artery for lower-lobe bleeding. (2,13,14,16-18,120) However, numerous additional vessels may give rise to a nonbronchial systemic arterial supply to the lung, such as the branches of the axillary arteries, the intercostals arteries, or the hepatic and gastric arteries. (9, 19, 126,127)

Subclavian artery angiography studies have demonstrated that the internal mammary artery, lateral thoracic artery and subscapular artery were the main hemorrhagic arteries. Corresponding subclavian artery angiography should be

performed after the hemorrhagic branches of descending aorta artery have been embolized for hemoptysis due to pulmonary tuberculosis, especially in cases with failed embolization, or complicated with severe pulmonary fibrosis, cavity formation, aspergilloma, pleural thickening, or postoperative thorax. The hemorrhagic arteries shown by subclavian artery angiography must be embolized. (127) If lower-lobe disease is present, an abdominal aortogram and examination of the inferior phrenic arteries should also be performed. If no systemic (bronchial or nonbronchial) arterial supply is identified, selective pulmonary arteriography should be performed in an attempt to identify a pulmonary arterial source such as a pseudoaneurysm or arteriovenous fistula. (15,16,111,124,128-130)

iv) IDENTIFICATION OF SPINAL SUPPLY

Anterior medullary arteries have a characteristic “hairpin” configuration at angiography. Radicular arteries are often visualized during BAE. Unintentional embolization of radicular arteries does not cause clinical problems like spinal cord ischemia. It has been stated that the presence of radicular arteries is not considered to be a contraindication for BAE. (3,66,117)

If there is some doubt concerning a midline branch on an anteroposterior film, an oblique film should be obtained to identify whether this branch does indeed enter the spinal canal. Tracheal and esophageal branches also originate

from the bronchial artery and may appear midline on anteroposterior films but do not feature the hairpin loop. Occasionally, a spinal artery branch will only be identified after partial distal embolization when the resistance of that vascular bed is elevated and smaller proximal branches are better opacified. (66) Some authors have advised the use of an intraarterial barbiturate as a provocative test in searching for an occult spinal artery contribution before bronchial artery embolization. (131,132) Transverse myelitis associated with BAE has more commonly been associated with the use of ionic contrast media. (133,134)

F) EVALUATION OF RECURRENT HEMOPTYSIS

Patients with mycetoma have been reported with high recurrence after initial embolization. (39) Recurrent nonmassive hemoptysis is also common in patients with cystic fibrosis, where these recurrent bleeds are debilitating and preclude routine postural drainage of other lung regions. (66,135,136)

In cases of recurrence in spite of accurate embolization of pathological arteries, the presence of bronchial arteries of anomalous origin should be considered. Embolization is more difficult in these cases and there is an increased risk of complications. (62) Selective pulmonary angiography is also performed in cavitary tuberculous patients with severe hemoptysis uncontrolled by previous bronchial and systemic arterial embolization which might reveal Rasmussen aneurysms.

These are effectively treated by steel coil occlusion. (46) The most significant factor affecting recurrence was whether the inflammation caused by the underlying disease was medically well controlled. (137)

5) COMPARISON OF CT AND CONVENTIONAL ANGIOGRAPHY

Multi–detector row helical CT angiography has been shown to provide more precise depiction of bronchial and nonbronchial systemic arteries than does conventional angiography(21) and can help in the planning of a focused and efficient nonbronchial systemic artery embolization, as was recently reported with single– detector row CT. (20) Bronchial arteries of anomalous origin are easily overlooked during bronchial artery embolization, even when complemented with arch aortography but are well depicted with extended thoracic CT angiography that includes the base of the neck and the upper abdomen. (63) Nonbronchial systemic artery embolization can be done at first intention because CT angiography can depict the type of nonbronchial supply,its origin and course accurately. (21) If CT angiography is not performed and the bronchial arteries are normal or in case of recurrence after successful bronchial artery embolization, subclavian angiography or abdominal aortography (for inferior phrenic arteries) must be performed in cases with upper lobe or lower lobe disease respectively. (17,127) If there is no nonbronchial systemic vessel, then pulmonary angiography must be done to detect

a possible Rasmussen aneurysm. (46) A recent study has shown that MDCT and conventional angiography have almost equal capability in depicting the ostia of bronchial arteries. 3D images of MDCT aids in the depiction of ectopic origin of bronchial arteries, enabling the interventional radiologists to perform successful embolization after direct catheterization of the ectopic vessel. (21)

6) EMBOLOTHERAPY FOR HEMOPTYSIS CONTROL

Bronchial artery embolization is a well-established, worthwhile, palliative control of severe as well as recurrent mild hemoptysis secondary to inflammatory disease. Indications for embolization have expanded to include not only severe and massive bouts of hemoptysis but also mild to chronic and intermittent episodes of hemoptysis as well. The procedure should be performed promptly when indicated, and, when good embolization techniques are used, complications are infrequent. (23,26,117,135,138)

i) TECHNIQUE

The goal of the embolization procedure varies, depending on whether the bleeding site has been located with some degree of reliability and whether there have been previous embolization procedures. If the site of hemorrhage is known, attention can be confined to embolization of bronchial arteries and collaterals supplying that area. (85) Distal embolization should be performed whenever

possible. If permanent proximal occlusion alone is performed, distal collaterals will invariably develop, and future access to the main bronchial artery may be lost. The average number of arteries embolized per patient was 2.5. (9) In cases of hemorrhage when the cause is not easily identified, or in cases of recurrence in spite of accurate embolization of pathological arteries, the presence of bronchial arteries of anomalous origin should be considered. Embolization is more difficult in these cases and there is an increased risk of complications. (62) The higher risk of subsequent complications is due to their frequent proximity to the vertebral and carotid arteries and to the difficulty in achieving stable selective catheterization of these arteries. (21,62,117)

Occasionally, a spinal artery branch will only be identified after partial distal embolization when the resistance of that vascular bed is elevated and smaller proximal branches are better opacified. (66) Embolization of a bronchial artery with a documented spinal artery contribution is controversial and depends on operator experience and the risk-benefit ratio of bronchial artery embolization (i.e., the clinical status of the patient) Clearly a catheter position distal to the spinal artery origin is preferential and is often achievable with modern coaxial systems. Anterior medullary arteries have a characteristic “hairpin” configuration at angiography. Radicular arteries are often visualized during BAE. In our experience, unintentional embolization of radicular arteries does not cause clinical

problems like spinal cord ischemia. It has been stated that the presence of radicular arteries is not considered to be a contraindication for BAE. (3,117,139) Superselective embolization is safer and more effective way to control hemoptysis than the ordinary (nonsuperselective) method. It lowers the incidence of spinal cord injury. (140)

ii) EMBOLIZING MATERIALS

The most commonly used embolic materials for bronchial artery embolization include Gelfoam and polyvinyl alcohol (PVA) particles. (2,14,23,122,123,136,138,139) Gelfoam (gelatin sponge) is the most commonly used material. It is a readily available, slowly resorbable material that can be used as individual pledgets, torpedoes, or part of a slurry. For initial distal occlusion, 0.5- to 2.0-mm cubes can be used followed by 3- to 4-mm pledgets or torpedoes for more proximal occlusion. Gelfoam pledgets are mixed with dilute contrast within a 1- or 3-ml syringe. Since the Gelfoam pledgets float within the contrast saline solution, the tip of the syringe should be pointed upward. A theoretical disadvantage of Gelfoam particles is that their resorption may lead to more rapid recanalization and recurrent bleeding. (141)

Enormous bronchial arteries with high flow and large systemic-to-pulmonary shunts sometimes encountered in cystic fibrosis may require the use of

coil embolization for safe and adequate occlusion. Coils should be 15 to 25 percent larger than the vessel diameter to avoid retrograde dislodgment, and the catheter should be well seated. (30,142-144) Coil embolization therapy is also used in the embolization of bronchial artery pseudoaneurysms. (43)

iii) NONBRONCHIAL SYSTEMIC ARTERY EMBOLIZATION

Persistent hemoptysis after a technically successful bronchial artery embolization constituted an indication for embolization of nonbronchial systemic arteries, which is always considered at second intention because of (a) the potential neurologic iatrogenic risks when embolizing these vessels, especially collaterals of the subclavian artery (owing to the proximity of the vertebral artery) and the intercostal and inferior phrenic arteries (owing to the likelihood of a major spinal cord supply from these branches), and (b) the lack of a constant relationship between arterial hypervascularity and bronchial bleeding. On the contrary, embolization of nonbronchial systemic arteries is systematically considered at first intention for the management of hemoptysis of congenital origin. (21) Massive hemoptysis can be effectively controlled by the embolization of intercostal trunks, if these are shown to supply the bleeding sites in patients who are poor candidates for surgery. If any important branch to the spinal cord is visualized on preliminary angiography, this procedure can be employed without complication if the

intercostal vessel is embolized distal to the origin of the anastomotic branch to the spinal cord. (13)

The internal mammary artery contributes to the perfusion of lesions responsible for hemoptysis when the basic lesion involves the pulmonary parenchyma adjacent to the anterior pleural surface. Initial distal occlusion of the internal mammary artery may improve the efficacy of embolization of this artery for hemoptysis. (69) Corresponding subclavian artery angiography should be performed after the hemorrhagic branches of descending aorta artery have been embolized for hemoptysis due to pulmonary tuberculosis, especially in cases with failed embolization, or complicated with severe pulmonary fibrosis, cavity formation, aspergilloma, pleural thickening, or postoperative thorax. The hemorrhagic arteries shown by subclavian artery angiography must be embolized. (127)

iv) COMPLICATIONS OF BAE

Complications of BAE procedures include subintimal dissection of the aorta leading to mediastinal hematoma, referred pain to the ipsilateral orbit , transient dysphagia , diaphragmatic paralysis , bronchoesophageal fistulas , transient thoracic pain, transient leg pain, bronchial arterial perforation by a guidewire, reflux of embolic material into the aorta and spinal cord complications. The latter

complication may be a Brown-Se´quard syndrome, paraparesis or complete paraplegia. (9,13,19,25,144) Transverse myelitis associated with BAE was common in the past and was associated with the use of ionic contrast media. Hence nonionic contrast agents should be routinely used. (133,134) Spinal infarction can occur with nonsuperselective embolization. (140) To lower the incidence of spinal cord injury, monitoring with somatosensory-evoked potentials has been proposed by some authors. (114) A recent study has shown that with preembolization MDCT angiography, no complications were encountered after the embolization of bronchial and nonbronchial systemic arteries. (21)

v) BAE EFFICACY

BAE has excellent immediate control of hemoptysis (77-100%) (16,23,26,93,117,138) The immediate effect was unfavorable in cases where feeder vessels were overlooked or the embolization of the intercostal arteries was insufficient. (137) Tamura et al. demonstrated long-term hemostasis in 70 percent of patients without documented pleural thickening, whereas this was achieved in only 29 percent of patients with significant pleural thickening. (94) BAE can also be done in patients with primary lung cancer despite the fact the vascular changes are subtle on angiography. (145)

While arterial embolization as initial treatment of hemoptysis is a highly useful procedure, this is a palliative procedure and potential for recurrence of hemoptysis exists as the lesion that has initially caused hemoptysis is not cured by the embolization. (39) Etiologic therapy aimed at removing the infection leading to chronic inflammation is the cure for tuberculosis and hemoptysis. (146) Surgery remains the procedure of choice in the treatment of massive hemoptysis caused by specific conditions, such as hydatid cyst, thoracic vascular injury, bronchial adenoma, and aspergilloma that is resistant to other therapies. (12) Even in surgical candidates, BAE is effective in preparing the patient for elective rather than high-risk emergency surgery.(7) Embolization of bronchial and systemic arteries is an effective method for treating acute severe hemoptysis from intracavitary aspergillomas, allowing the patient time to recover for definitive surgical management. (147)

MATERIALS AND METHODS

PATIENT POPULATION

28 consecutive patients (25 men, 3 women; mean age, 40.2 years; range, 18–65 years) referred to our institution in a six-month period for endovascular treatment of hemoptysis underwent multi–detector row helical CT angiography as part of pretherapeutic evaluation.

Prior to the introduction of multi–detector row helical CT technology, each patient referred for the management of bronchial bleeding at our institution underwent a nonenhanced CT examination of the thorax. Since multi–detector row helical CT offers the possibility of providing additional information regarding the source of bronchial bleeding, the inclusion of a CT angiography study was approved by our institutional review board in the clinical context of hemoptysis.

Care was taken to avoid administration of contrast material if contraindications existed, such as renal insufficiency (creatinine level greater than 150 mmol/L), iodine intolerance, or use of biguanide in cases of diabetes mellitus. The present study is a retrospective review of the imaging studies performed in these patients. The average quantity of hemoptysis per episode prior to embolization was about 160 ml (range, 5 - 1000ml). The number of hemoptysis

episodes ranged from one to more than hundred and the duration of hemoptysis ranged from one day to 12 years.

History of ATT intake for tuberculosis was present in 23 patients. One patient was sputum positive for tubberculosis during evaluation and five patients were diabetic. Mean hemoglobin of patients was 10.7 grams/100ml (range, 4.6 – 17 grams/100ml). All patients had either clinical or imaging features of Tuberculosis.

The mean quantity of hemoptysis in last 3 days prior to admission in patients with cavity was 422ml whereas it was 248 ml in patients without cavity. The mean quantity of hemoptysis in last 3 days prior to admission in patients with aspergilloma was 451 ml, whereas it was 324 ml in patients without aspergilloma.

MDCT ANGIOGRAPHY

CT angiography was performed with a 64–detector row scanner (Brilliance 64; Philips, Holland) (Figure 4) for all patients (120 kV, 60–100 mAs, rotation time of 0.5 second, 0.75-mm collimation, pitch of 1.5). The respective mean height of the volume scanned and the mean duration of data acquisition were 350 mm and 10 seconds. (Figure 5)

Patients received 80–100 mL of contrast material (iohexol, Omnipaque 350; Amersham Health, Carrigtohill, Ireland) with 350 mg of iodine per milliliter and

an injection rate of 4 mL/sec. The automatic bolus triggering software program was systematically applied, with a circular region of interest positioned at the level of the ascending aorta and a threshold for triggering data acquisition preset at 100 HU after an initial scanogram. (Figures 6,7)

From each data set, three series of images were systematically reconstructed as follows: contiguous 1-mm-thick transverse CT scans viewed at mediastinal and lung window settings, oblique coronal and sagittal maximum intensity projections (MIPs), and three-dimensional volume- rendered images of the thoracic vascular structures.

CT Analysis

CT analysis is done in the following steps in cases of life threatening hemoptysis.

- STEP 1: Study Lung parenchyma for disease process
- STEP 2: Measure Pleural thickening
- STEP 3: Determine the Bleeding Bronchial arteries
- STEP 4: Localise the Origin of the Bronchial Artery in 3 planes
- STEP 5: Map proximal course of Bronchial Artery
- STEP 6: Search and localise Nonbronchial Systemic Arteries and pulmonary vessels causing hemoptysis

STEP 1: Study Lung parenchyma for disease process

The lung parenchyma is studied in detail, mainly looking out for cavities, bronchiectasis and any mass lesion communicating with bronchi. Since most of the patients were having clinical or radiological tuberculosis, the main foci was on Cavities and associated Bronchiectasis. Aspergilloma within old tuberculous cavity is an important cause for recurrent hemoptysis and hence was specially searched for, especially in diabetic patients. (Figure 8) Air space disease indicates active disease and has to be noted. The analysis of lung parenchyma will help to lateralize the disease process when lesions are present in both lungs on chest radiography. It will also locate the probable lesion causing the bleed.

STEP 2: Measure Pleural thickening

Pleural thickening has to be measured on both sides between the visceral pleura – lung interface and the parietal pleura – rib interface. Apical predominance of lesions is noted in tuberculosis, and hence apical pleural thickening is seen in many patients. (Figure 9) Thickening of the apical pleura more than 3mm was associated with non bronchial systemic supply, especially from internal mammary artery leading to recurrent hemoptysis. Also, basal pleural thickening is doubted to be associated with supply from inferior phrenic artery.

STEP 3: Determine the Bleeding Bronchial arteries

Signs of bleeding vessel on MDCT

- Hypertrophied vessel – diameter more than 1.5 mm (Figure 10)
- Tortuosity of the vessel (Figure 11, 12)
- Parenchymal staining
- Broncho pulmonary shunt (Figure 13)
- Active leak from vessel

STEP 4: Localise the Origin of Bronchial Artery in 3 planes

Next, the origin of the bleeding bronchial artery has to be localized in three planes. (Figure 14) In the Z- axis (Craniocaudal), the carina, the vertebral body, or the left main bronchus can be used as a reference. (Figure 15,16) However, during angiography, it is seen that the left main bronchus is easily recognized and can be consistently used as a reference level. In the X and Y axes (axial), the origin of the bronchial artery is plotted with reference to a clock face. (Figure 17) All bronchial arteries and the bleeding intercostals arteries can be localized in the axial plane by this method to assist the interventional radiologist in entering the bleeding vessel.

STEP 5: Map proximal course of Bronchial Artery

The proximal course of the pathologic bronchial or intercostobronchial artery is then mapped with help of Maximum Intensity Projection (MIP), Curved MIP or Shaded Surface Display (SSD) techniques (Figures 18 – 20) . Since intercostobronchial artery origin of right bronchial artery is common, it is important to note the division of the intercostals and bronchial trunks to avoid intercostals artery embolisation which can give rise to severe pain and other complications. It is important to note the level of origin of any prominent radicular artery or an ectopic artery of adamkiewicz from the bronchial or intercostobronchial artery. Rarely, coronary or phrenic branches can arise from the bleeding vessel and the origin of these vessels must also be mapped in order to avoid them by super selective embolisation.

STEP 6: Search and localise Nonbronchial Systemic Arteries and pulmonary vessels causing hemoptysis

Various nonbronchial systemic arteries have been described as potential causes for primary and recurrent hemoptysis and it is necessary to identify these vessels after identification of the bronchial arteries. These vessels assume importance especially when the bronchial arteries are of normal size and when there is marked pleural thickening. When there is no hypertrophied nonbronchial

systemic vessel, the pulmonary vessels are finally analysed, since they can rarely be a source of life threatening hemoptysis. Rasmussen aneurysms from the pulmonary vasculature can be seen in the wall of tuberculous cavities and can bleed profusely.

CONVENTIONAL ANGIOGRAPHY

Angiography was performed after MDCT angiography. The mean time interval between admission and MDCT was 7 days (range, 1-28 days). The mean time interval between MDCT and catheter angioembolization was 3 days (range, 1-6days) Angiography was was done with a 500mA Shimadzu(Japan) Fluoroscopy machine. (Figure 21) All patients had a right transfemoral approach with arterial puncture by modified Seldinger's technique. 6 F Sheath was used for all cases and a 5F or 6 F Cobra Catheter was used to hook the bronchial arteries. Nonionic iodinated contrast material (Iohexol) was used and on an average, about 150 ml of contrast was used per patient. The mean duration of angioembolization (from sheath insertion to sheath withdrawl) was 43 minutes.

Flush aortography was done in all patients prior to a search for the bronchial arteries. Since it is a life saving procedure, the information regarding the bronchial artery size and ostial location was utilized during the search for pathological bronchial arteries. Initially, the bronchial artery on the side with the major

parenchymal disease process was searched for. Search for multiple bronchial arteries was then made.

The contralateral bronchial arteries were also checked in every case. Then, a search for nonbronchial systemic arteries was done whenvever there was a significant pleural thickening. Not all nonbronchial systemic arteries detected at MDCT was searched by conventional angiography, since it was a life saving procedure and the aim was to embolize the pathological bronchial artery first and clinically stabilize the patient. The number of bronchial arteries on each side and their ostial position with respect to vertebral body level was noted.

The depiction of intra and extra pulmonary course of bronchial arteries was also noted. The type of nonbronchial artery and its size and level of origin was also noted. A search was also made to detect any pseudoaneurysm of bronchial artery. Finally, the images were analysed for any prominent spinal medullary or radicular artery arising from the bronchial or nonbronchial systemic artery supplying the diseased lung parenchyma.

RESULTS

A) MDCT

i) ASSESSMENT OF LUNG PARENCHYMA AND PLEURA

Disease process capable of producing hemoptysis noted in CT – Maximum Intensity Projection in all 28 cases. It was lateralised to one side in 17 cases. (Right – 7, Left – 10) It was bilateral (Not Localised to one side) in 11 cases. Cavity was present in 18 cases out of the total 28 cases (64.3%). It was present only in Right Side in 7 cases and only in Left side in 6 cases. Cavity present bilaterally in 5 cases. Bronchiectasis was noted in 16 out of 28 cases (57.1%). Cavity with Bronchiectasis was present in 8 out of 28 cases (28.6%). Aspergilloma was present in 8 out of 28 cases (28.6%). Diabetes was present in 5 patients. Diabetes with Aspergilloma was noted in 2 patients

The mean right pleural thickness was 3.3mm. (Min- 0mm, Max - 15.8mm). 12 Patients had Right Pleural thickening more than 3mm. In the 12 patients with right non bronchial systemic supply, the mean right pleural thickness was 5.8mm. (Min-2.1mm, Max - 15.8mm). In the 16 patients without right non bronchial systemic supply, the mean Right Pleural thickness was 1.35mm. (Min - 0 mm, Max - 7.7mm). In the12 patients with Rt Pleural thickness more than 3mm, Right Non Bronchial supply was noted in 9 patients (75%).

The mean left pleural thickness was 4.12mm. (Min- 0mm, Max – 12.9mm). 16 Patients had left Pleural thickening more than 3mm. In the 16 patients with left non bronchial systemic supply, the mean left pleural thickness was 6.9 mm. (Min- 0 mm, Max – 12.9 mm). In the 12 patients without left non bronchial systemic supply, the mean left Pleural thickness was 1.4 mm. (Min - 0 mm, Max – 6 mm). In the16 patients with Lt Pleural thickness more than 3mm, Left Non Bronchial supply was noted in 13 patients (81.25%).

RT PL THICK >3MM * RT NON BRONCHIAL SYSTEMIC Crosstabulation

			RT NON BRONCHIAL SYSTEMIC		
			PRESENT	ABSENT	Total
RT PL THICK >3MM	YES	Count	9	3	12
		% of Total	32.1%	10.7%	42.9%
	NO	Count	3	13	16
		% of Total	10.7%	46.4%	57.1%
Total		Count	12	16	28
		% of Total	42.9%	57.1%	100.0%

Sensitivity =75 % ; Specificity = 81.25 %

Positive Predicitve Value = 75 % ; Negative Predicitve Value = 81.25 %

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	8.859[b]	1	.003		
Continuity Correction [a]	6.711	1	.010		
Likelihood Ratio	9.304	1	.002		
Fisher's Exact Test				.006	.004
Linear-by-Linear Association	8.543	1	.003		
N of Valid Cases	28				

LT PL THICK >3MM * LT NON BRONCHIAL SYSTEMIC Crosstabulation

			LT NON BRONCHIAL SYSTEMIC		
			PRESENT	ABSENT	Total
LT PL THICK >3MM	YES	Count	13	3	16
		% of Total	46.4%	10.7%	57.1%
	NO	Count	1	11	12
		% of Total	3.6%	39.3%	42.9%
Total		Count	14	14	28
		% of Total	50.0%	50.0%	100.0%

Sensitivity = 92.86 % ; Specificity = 78.57 %

Positive Predicitve Value = 81.25 % ; Negative Predicitve Value = 91.67 %

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	14.583[b]	1	.000		
Continuity Correction[a]	11.813	1	.001		
Likelihood Ratio	16.490	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	14.063	1	.000		
N of Valid Cases	28				

ii) RIGHT BRONCHIAL ARTERIES

Right Bronchial Arteries were noted in 28 out of 28 cases(100%). Totally 43 right bronchial arteries were visualized. 17 cases had single bronchial artery, 7 cases had double bronchial artery and 4 cases had triple bronchial artery supply.

On an average, 1.54 bronchial arteries were noted per case. Intercostobronchial origin of right bronchial artery was noted in 25 out of 28 cases

(89.3%) The mean diameter of Right bronchial artery was 1.635mm. Hypertrophied Right Bronchial artery (more than 1.5mm) was noted in 17 out of 28 cases (60.7%). 20 out of the 43 right bronchial arteries (46.5%) were found to be hypertrophied. The right bronchial arteries were found to have their origin at D4 level in 2 arteries, D5 level in 26 arteries, D6 level in 13 arteries and D7 level in 2 arteries. (Figure 22) The orthotopic origin of Right bronchial artery (D5 and D6level) was noted in 39 out of 43 arteries (91%). (Figure 23)

Ostia(clock position) of right bronchial artery was at 9'oclock in 25 arteries, 10'o clock in 4 arteries, 11'o clock in 3 arteries, 12'o clock in 9 arteies and at 1'o clock in 2 arteries. 9 and 10 o clock Ostial position of right bronchial artery was noted in 29 out of 43 Arteries (67.3%). (Figure 24)

The right bronchial arteries excluding the common trunk of origin were found to have their origin at D4 level in 1 artery, D5 level in 19 arteries, D6 level in 7 arteries and D7 level in 1 artery. Orthotopic origin (D5 and D6 origin) of Right bronchial arteries excluding Common trunk of origin was noted in 26 out of 28 Arteries (92.9%). Ostia(clock position) of right bronchial artery excluding common trunk of origin was at 9'oclock in 25 arteries, 10'o clock in 2 arteries, and at 1'o clock in 1 arteries. 9 and 10 o clock Ostial position of right bronchial artery excluding common trunk was noted in 27 out of 28 Arteries (96.4%). (Figure 25,26)

Direct origin of Right Bronchial arteries (as opposed to intercostobronchial origin) were noted in 3 arteries. All 3 arteries arose at D5 level. They had their ostial location at 9'oclock, 10'o clock and 1'0 o clock positon. 9 and 10 o clock Ostial position of Direct right bronchial arteries was 2 out of 3 Arteries (66.7%)

MDCT showed signs of hemoptysis producing disease in right lung alone in 7 out of 28 cases (25%)

	CT >1.5mm RBA	CT <1.5mm RBA
CT Positive Only Right Lung Disease	6	1
CT Negative Only Right Lung Disease	11	10

Sensitivity = 35.29% ; Specificity= 90.91 %

Positive Predicitve Value = 85.71 % ; Negative Predicitve Value = 47.6 %

Analysis: 'N-1' Chi squared = 2.36, P = 0.12

MDCT signs of Hemoptysis Producing disease in right lung and bilateral disease was noted in 18 out of 28 cases (64.3%)

	CT >1.5mm RBA	CT <1.5mm RBA
CT Positive Probable Right Lung Disease	15	3
CT Negative Probable Right Lung Disease	2	8

Sensitivity = 88.24% ; Specificity= 72.73%

Positive Predicitve Value = 83.33 % ; Negative Predicitve Value = 80 %

Analysis: 'N-1' Chi squared = 10.42, P = 0.001

In Cases with Probable Right Lung disease by CT

	CT Significant RBA Present	CT Significant RBA Absent
Catheter Angio RBA Present	14	2
Catheter Angio RBA Absent	1	1

Sensitivity = 93.33% ; Specificity= 33.33%

Positive Predicitve Value = 87.5 % ; Negative Predicitve Value = 50 %

Analysis: Fishers Exact test 1-tail P = 0.314

No. of Right Bronchial Arteries Detected Per Patient on MDCT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	17	60.7	60.7	60.7
	2	7	25.0	25.0	85.7
	3	4	14.3	14.3	100.0
	Total	28	100.0	100.0	

iii) RIGHT INTERCOSTOBRONCHIAL ARTERY

Right Intercostobronchial artery was visualised in 25 out of 28 cases (89.3%) and in 25 out of 43 Arteries (58.1%) All Right Intercostobronchial arteries were single vessels. The Mean Diameter of Intercostobronchial artery was 2.3mm. The Origin of Right Intercostobronchial (N=25) was at D4level in 1 case, D5 level in 16 cases, D6 level in 7 cases and D7 level in 1 case. D5 and D6 origin of Right Intercostobronchial was noted in 23 out of 25 Arteries or cases (92%). The Ostial position of Right Intercostobronchial(N=25) was noted at 9'oclock in 21 cases,

10’o clock in 3 cases and 11’o clock in 1 case. 9 and 10 o clock Ostial position of Right Intercostobronchial was noted in 24 out of 25 cases (96%) (Figure 27)

iv) LEFT BRONCHIAL ARTERIES

Left Bronchial Arteries were noted in 28 out of 28 cases (100%). (Figure 28) Totally, 46 left bronchial arteries were visualized in 28 cases. A maximum of 2 bronchial arteries were noted per patient. Single left bronchial artery was noted in 10 cases and double left bronchial supply in 18 cases. There was no case with triple left bronchial supply. On an average, 1.64 bronchial arteries were noted per case. Intercostobronchial origin of left bronchial artery was not noted in any case. The mean Diameter of left bronchial artery was found to be 1.478 mm. Hypertrophy of left bronchial artery (more than 1.5mm diameter) was noted in 19 out of 28 cases (67.9%) or 20 out of 46 Arteries (43.5%)

The origin of any left bronchial artery (N=46): was noted at D4 level in 3 arteries, D5 level in 20 arteries=3, D6 level in 19 arteries and D7 level in 4 arteries. D5 and D6 origin of any left bronchial artery was noted in 39 out of 46 Arteries (84.8%) Ostial position of any Left bronchial artery was noted at 9’o clock in 6 arteries, 10’o clock in 1 artery, 11’0 clock in 9 arteries, 12’o clock in 20 arteries, 1’o clock in 10 arteries and 2’o clock position in 1 artery. 11 to 1 o clock Ostial position of any left bronchial artery was noted in 39 out of 46 Arteries (84.8%).

The origin of left bronchial artery excluding common trunks (N=31) was noted at D4 level in 2 arteries, D5 level in 12 arteries, D6 level in 14 arteries and D7level in 3 arteries. D5 and D6 origin of LBA Excluding Common Trunks = 26 out of 31 Arteries = 83.9% The ostial position of left bronchial artery excluding common trunks(N=31) was at 9'o clock position in 2 arteries, 10'o clock position in 1 artery, 11'o clock position in7arteries, 12'o clock position in 12 arteries, 1'o clock position in 8 arteries and 2'o clock position in 1 artery. 11 to 1 o clock Ostial position ofleft bronchial artery excluding Common Trunks was noted in 27 out of 31 Arteries =(87.1%) (Figure 29,30)

MDCT showed signs of hemoptysis producing disease in left lung alone in 10 out of 28 cases (35.7%)

	CT >1.5mm LBA	CT <1.5mm LBA
CT Positive Only Left Lung Disease	9	1
CT Negative Only Left Lung Disease	10	8

Sensitivity = 47.37% ; Specificity= 88.89 %

Positive Predicitve Value = 90 % ; Negative Predicitve Value = 55.55 %

Analysis: 'N-1' Chi squared = 3.37, P = 0.07

MDCT signs of Hemoptysis Producing disease in left lung and bilateral disease was noted in 21 out of 28 cases (75%)

	CT >1.5mm LBA	CT <1.5mm LBA
CT Positive Probable Left Lung Disease	18	3
CT Negative Probable Left Lung Disease	1	6

Sensitivity = 94.74% ; Specificity= 66.67%

Positive Predicitve Value = 85.71 %; Negative Predicitve Value = 85.71 %

Analysis: 'N-1' Chi squared = 11.84, P = 0.001

In Cases with Probable Lt Lung disease by CT

	CT Significant LBA Present	CT Significant LBA Absent
Catheter Angio LBA Present	12	1
Catheter Angio LBA Absent	6	2

Sensitivity = 66.67%; Specificity= 66.67%

Positive Predicitve Value = 92.3 % ; Negative Predicitve Value = 33.33 %

Analysis: 'N-1' Chi squared = 1.15, P = 0.3

No. of Left Bronchial Arteries Detected Per Patient on MDCT

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	10	35.7	35.7	35.7
	2	18	64.3	64.3	100.0
	Total	28	100.0	100.0	

v) COMMON TRUNK BRONCHIAL ARTERY

Common Trunk for right and left Bronchial Artery was noted in 13 out of 28 patients (46.4%). Totally 15 common trunk arteries were noted. 11 patients had single common trunk and 2 patients had two common trunks. Origin of Common trunk artery (N=15) was at D4 level in 1 artery, D5 level in 7 arteries, D6 level in 6 arteries and D7 level in 1 artery. D5 and D6 origin of Common trunk artery was noted in 13 out of 15 Arteries (86.7%). The ostial position of common trunk artery (N=15) was at 9'o clock position in 3 arteries, 11'o clock position in2 arteries, 12'o clock position in 8 arteries and 1'o clock position in 2 arteries. 9 and 10 o clock Ostial position of Common trunk artery was noted in 3 out of 15 cases (20%). 11 to 1 o clock Ostial position of Common trunk artery 12 out of 15 cases(80%)

vi) NONBRONCHIAL SYSTEMIC ARTERIES

Nonbronchial Systemic supply was noted on the right side in 12 out of 28 patients (42.9%). Totally, 23 Non Bronchial Systemic Arteries were noted on Right side. Nonbronchial Systemic supply was noted on the left side in 14 out of 28 patients (50%). Totally, 41 Non Bronchial Systemic Arteries were noted on left side. (Figures 33-39) The mean diameter of right internal mammary artery in all cases (N=28) was noted to be 2.64 mm. (Min = 1.8mm. Max = 4.9mm)

Nonbronchial Systemic supply from right internal mammary artery was noted in 6 cases out of 28 (21.4%). Mean diameter of right internal mammary artery was noted in these cases to be 3.77mm. (Min = 3mm. Max = 4.9mm) No Nonbronchial Systemic supply from right internal mammary artery was noted in in 22 out of 28 cases (78.6 diameter of right internal mammary artery was noted in these cases to be 2.33mm. (Min = 1.8mm. Max = 2.9mm)

The mean diameter of left internal mammary artery in all cases (N=28) was noted to be 2.81 mm. (Min = 1.5mm. Max = 4.7mm) Nonbronchial Systemic supply from left internal mammary artery was noted in 12 cases out of 28 (42.8%). Mean diameter of left internal mammary artery was noted in these cases to be 3.8mm. (Min = 3.1mm. Max = 4.7mm) No Nonbronchial Systemic supply from left internal mammary artery was noted in in 16 out of 28 cases (57.1% diameter of left internal mammary artery was noted in these cases to be 2.07mm. (Min = 1.5mm. Max = 2.8mm)

Between D4 and D7 level, the right intercostal arteries in all 28 patients were noted to originate from the descending thoracic aorta between 9 and 10'o clock position (100%). (Figure 31) Between D4 and D7 level, the left intercostal arteries in all 28 patients were noted to originate from the descending thoracic aorta between 6 and 7'o clock position (100%). (Figure 31)

No. of Non Bronchial Systemic Arteries Detected Per Patient on Right Side

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	16	57.1	57.1	57.1
	1	6	21.4	21.4	78.6
	2	3	10.7	10.7	89.3
	3	2	7.1	7.1	96.4
	5	1	3.6	3.6	100.0
	Total	28	100.0	100.0	

ARTERY	NO	PERCENTAGE
RIMA	6	26.10%
Rt Intercostal	8	34.80%
Rt Thyrocervical Trunk	2	8.70%
Rt Infr Phrenic	2	8.70%
Rt SCA	1	4.30%
Rt Costocervical Trunk	2	8.70%
Rt Acromiothoracic artery	1	4.30%
Rt Pericardiophrenic artery	1	4.30%

No. of Non Bronchial Systemic Arteries Detected Per Patient on Left Side

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	14	50.0	50.0	50.0
	1	3	10.7	10.7	60.7
	2	1	3.6	3.6	64.3
	3	1	3.6	3.6	67.9
	4	2	7.1	7.1	75.0
	5	2	7.1	7.1	82.1
	6	3	10.7	10.7	92.9
	9	1	3.6	3.6	96.4
	12	1	3.6	3.6	100.0
	Total	28	100.0	100.0	

ARTERY	NO	PERCENTAGE
LIMA	12	29.30%
Lt Intercostal	10	24.40%
Lt Thyrocervical Trunk	2	4.90%
Lt Infr Phrenic	6	14.60%
Lt SCA	7	17.10%
Lt costocervical trunk	1	2.40%
Lt Gastric	1	2.40%
Lt Hepatic	1	2.40%
Lt Lateral Thoracic	1	2.40%

RIMA > 3MM * RIMA - PATH Crosstabulation

			RIMA - PATH		
			PRESENT	ABSENT	Total
RIMA > 3MM	YES	Count	6	0	6
		% of Total	21.4%	.0%	21.4%
	NO	Count	0	22	22
		% of Total	.0%	78.6%	78.6%
Total		Count	6	22	28
		% of Total	21.4%	78.6%	100.0%

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	28.000[b]	1	.000		
Continuity Correction[a]	22.376	1	.000		
Likelihood Ratio	29.096	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	27.000	1	.000		
N of Valid Cases	28				

LIMA > 3MM * LIMA - PATH Crosstabulation

			LIMA - PATH		
			PRESENT	ABSENT	Total
LIMA > 3MM	YES	Count	12	0	12
		% of Total	42.9%	.0%	42.9%
	NO	Count	0	16	16
		% of Total	.0%	57.1%	57.1%
Total		Count	12	16	28
		% of Total	42.9%	57.1%	100.0%

Sensitivity = 100%; Specificity = 100%

Positive Predictive Value = 100 %; Negative Predictive Value = 100 %

Chi-Square Tests

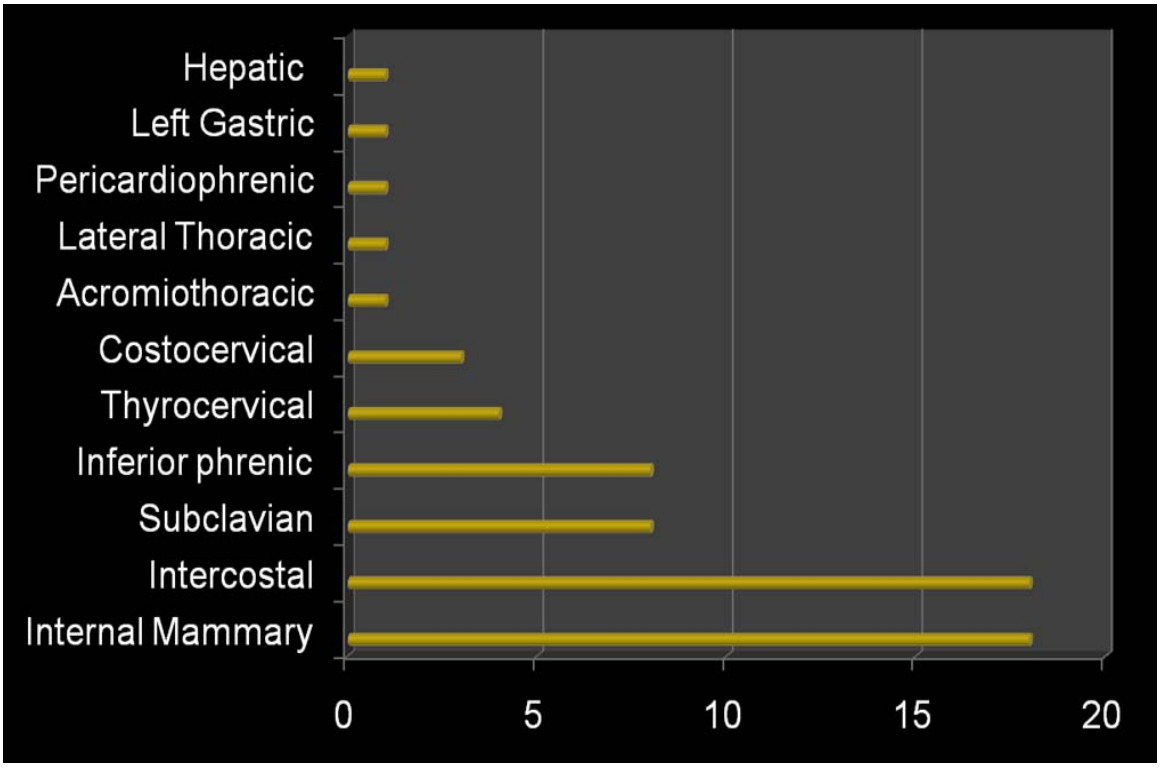
	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	28.000[b]	1	.000		
Continuity Correction[a]	24.066	1	.000		
Likelihood Ratio	38.243	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	27.000	1	.000		
N of Valid Cases	28				

	NON BRONCHIAL SUPPLY PRESENT	NON BRONCHIAL SUPPLY ABSENT
INF PHR >2 MM	6	4
INF PHR <2 MM	2	44

Sensitivity = 75%; Specificity = 91.67%

Positive Predictive Value = 60 %; Negative Predictive Value = 95.6 %

Analysis: 'N-1' Chi squared = 20.41, P < 0.0001



FREQUENCY OF NONBRONCHIAL SYSTEMIC ARTERIES DETECTED IN THE STUDY

B) CONVENTIONAL ANGIOGRAPHY

Successful embolization was done in 25 out of the 28 cases of life threatening hemoptysis. 21 Right bronchial arteries were visualised by conventional angiography and the intra and extrapulmonary course were clearly seen in all these cases. (Figure 40) Increased tortuosity of the vessel was noted in 17 of these 21 arteries. 17 of the 21 right bronchial arteries had an intercostobronchial origin. 20 out of 21 right bronchial arteries were embolized successfully with gelfoam slurry. (Figure 41,42) Parenchymal staining was noted

in 17 of 21 right bronchial arteries. (Figure 43) Broncho pulmonary shunting was noted in 14 out of 21 right bronchial arteries.

Right Bronchial Arteries identified on Conventional Angiography

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Vessel Not Indentified	9	32.1	32.1	32.1
	Vessel Indentified	19	67.9	67.9	100.0
	Total	28	100.0	100.0	

No. of Right Bronchial Arteries Detected on Angiography Per Patient

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	9	32.1	32.1	32.1
	1	17	60.7	60.7	92.9
	2	2	7.1	7.1	100.0
	Total	28	100.0	100.0	

No. of Right Bronchial Arteries Embolised Per Patient

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	10	35.7	35.7	35.7
	1	16	57.1	57.1	92.9
	2	2	7.1	7.1	100.0
	Total	28	100.0	100.0	

Non bronchial systemic supply was noted on the right side in 7 out of the 28 patients. Out of these 7 patients, intercostal artery supply was present in all cases and an pateint had an internal mammary supply in addition. (Figure 44,45)

Right Sided Non Bronchial Systemic Arteries identified on Conventional Angiography

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Vessel Not Indentified	21	75.0	75.0	75.0
	Vessel Indentified	7	25.0	25.0	100.0
	Total	28	100.0	100.0	

No. of Nonbronchial Systemic Arteries Deteced Per Patient on Right Side on Angiography

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	21	75.0	75.0	75.0
	1	6	21.4	21.4	96.4
	2	1	3.6	3.6	100.0
	Total	28	100.0	100.0	

17 Left bronchial arteries were visualised by conventional angiography and the intra and extrapulmonary course were clearly seen in all these cases. (Figure 46) All the left bronchial arteries were direct branches from the descending thoracic aorta. 15 out of the 17 left bronchial arteries were embolized successfully with gelfoam slurry. Parenchymal staining was noted in all of the 15 left bronchial arteries. Broncho pulmonary shunting was noted in 11 out of the 15 left bronchial arteries. (Figure 47)

Left Bronchial Arteries identified on Conventional Angiography

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Vessel Not Indentified	15	53.6	53.6	53.6
	Vessel Indentified	13	46.4	46.4	100.0
	Total	28	100.0	100.0	

No. of Left Bronchial Arteries Detected on Angiography Per Patient

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	15	53.6	53.6	53.6
	1	9	32.1	32.1	85.7
	2	4	14.3	14.3	100.0
	Total	28	100.0	100.0	

No. of Left Bronchial Arteries Embolised Per Patient

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	16	57.1	57.1	57.1
	1	9	32.1	32.1	89.3
	2	3	10.7	10.7	100.0
	Total	28	100.0	100.0	

Non bronchial systemic supply was noted on the left side in 8 out of the 28 patients. Left intercostal arteires, left subclavian artery branch, left inferior phrenic artery were the nonbronchial systemic arteries detected on the left side, with the left intercostals being the most common, noted in 6 out of the 8 patients with left nonbronchial systemic artery supply. (Figures 48,49)

Left Sided Non Bronchial Systemic Arteries identified on Conventional Angiography

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Vessel Not Indentified	20	71.4	71.4	71.4
	Vessel Indentified	8	28.6	28.6	100.0
	Total	28	100.0	100.0	

No. of Nonbronchial Systemic Arteries Deteced Per Patient on Left Side on Angiography

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	20	71.4	71.4	71.4
	1	7	25.0	25.0	96.4
	2	1	3.6	3.6	100.0
	Total	28	100.0	100.0	

Common trunk of origin was noted in 4 out of the 28 patients. No prominent radicular or medullary artery was identified. No bronchial artery pseudoaneurysm was identified.

C) COMPARISON OF MDCT AND CONVENTIONAL ANGIOGRAPHY

ANGIOGRAPHICALLY DETECTED * MDCT DETECTED

RIGHT BRONCHIAL ARTERIES - CROSS TABULATION

			NO. OF RT BRONCHIAL ARTERY- CT	
			Vessel Indentified	Total
NO. OF RT BRONCHI ARTERIES- ANG	Vessel Not Indentifie	Count	9	9
		% of Total	32.1%	32.1%
	Vessel Indentified	Count	19	19
		% of Total	67.9%	67.9%
Total		Count	28	28
		% of Total	100.0%	100.0%

ANGIOGRAPHICALLY DETECTED * MDCT DETECTED

LEFT BRONCHIAL ARTERIES - CROSS TABULATION

			NO. OF LT BRONCHIAL ARTERY-CT	
			Vessel Indentified	Total
NO. OF LT BRONCHI ARTERIES - ANG	Vessel Not Indentifi	Count	15	15
		% of Tota	53.6%	53.6%
	Vessel Indentified	Count	13	13
		% of Tota	46.4%	46.4%
Total		Count	28	28
		% of Tota	100.0%	100.0%

T-TEST

Group Statistics

	DIAGNOSI	N	Mean	Std. Deviation	Std. Error Mean
NO. OF RT BRONCH ARTERIES	ANGIO	28	.75	.585	.111
	CT	28	1.54	.744	.141
NO. OF LT BRONCH ARTERIES	ANGIO	28	.61	.737	.139
	CT	28	1.64	.488	.092
NON BRONCHIAL SYSTEMIC - RIGHT	ANGIO	28	.29	.535	.101
	CT	28	.82	1.249	.236
NON BRONCHIAL SYSTEMIC - LEFT	ANGIO	28	.32	.548	.104
	CT	28	2.32	3.221	.609

INDEPENDENT SAMPLES TEST

		Levene's Test for Equality of Variance		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
NO. OF RT BRONC ARTERIES	Equal variance assumed	3.659	.061	-4.390	54	.000	-.786	.179	-1.145	-.427
	Equal variance not assumed			-4.390	51.151	.000	-.786	.179	-1.145	-.426
NO. OF LT BRONC ARTERIES	Equal variance assumed	8.249	.006	-6.198	54	.000	-1.036	.167	-1.371	-.701
	Equal variance not assumed			-6.198	46.844	.000	-1.036	.167	-1.372	-.700
NON BRONCHIAL SYSTEMIC - RIGH	Equal variance assumed	9.839	.003	-2.087	54	.042	-.536	.257	-1.050	-.021
	Equal variance not assumed			-2.087	36.572	.044	-.536	.257	-1.056	-.015
NON BRONCHIAL SYSTEMIC - LEFT	Equal variance assumed	39.940	.000	-3.239	54	.002	-2.000	.617	-3.238	-.762
	Equal variance not assumed			-3.239	28.562	.003	-2.000	.617	-3.264	-.736

NPAR TESTS

MANN-WHITNEY TEST

Test Statistics[a]

	NO. OF RT BRONCHIAL ARTERIES	NO. OF LT BRONCHIAL ARTERIES	NON BRONCHIAL SYSTEMIC - RIGHT	NON BRONCHIAL SYSTEMIC - LEFT
Mann-Whitney U	185.500	121.000	305.500	266.000
Wilcoxon W	591.500	527.000	711.500	672.000
Z	-3.862	-4.730	-1.692	-2.352
Asymp. Sig. (2-tailed)	.000	.000	.091	.019

a. Grouping Variable: DIAGNOSIS

DISCUSSION

Since MDCT of the Chest for the search of bronchial and nonbronchial arteries revealed many other data regarding the diseased lung parenchyma, the data was analysed to find if the detection of the disease could lateralize the site of origin of hemoptysis. It was found that the coronal Maximal intensity projection of the lungs was useful in depicting disease and disease process capable of producing hemoptysis was noted in all 28 cases. The diseases were unilateral in 60.7% cases. However, since disease process capable of producing hemoptysis was noted in 39.3% of cases, there is a need for another investigative modality to lateralize the side of bleed.

When the MDCT findings of lung parenchymal disease were checked with hypertrophy of bronchial arteries on the right side, it was found to have a sensitivity of 88% and specificity of 72%. On the left side, the sensitivity was 94.7% and specificity was 66.67 %. On both sides, the positive and negative predictive values were more than 80%. The P value was found to be 0.001 on both sides, indicating that it was highly significant.

Regarding the causative factors for hemoptysis, it was found that cavitary disease due to tuberculosis was the commonest (64.3%) followed by bronchiectasis

(57.1%). A combination of cavity with bronchiectasis was noted in 28.6% of cases.

Regarding the predictors for nonbronchial artery supply, the pleural thickness was assessed in every case. It was found that significant pleural thickening (more than 3mm) was related with a non bronchial systemic supply. On the right side, significant pleural thickening was noted to be 75% sensitive and 81.25% specific for the detection of nonbronchial arterial supply. On the left side, it was noted to be 92.86% sensitive and 78.57% specific for the detection of nonbronchial arterial supply. On both sides, they were found to be statistically significant.

Since the bronchial circulation is the major source of bronchial bleeding and because bronchial arteries vary considerably in their numbers and sites of origin, the anatomic characteristics of bronchial arteries ipsilateral to the side of bleeding were analyzed. 38 bronchial arteries were identified on conventional angiogram compared with 89 bronchial arteries by MDCT. On an average, 3.18 bronchial arteries were detected per case by MDCT. Hence, the detection rate of bronchial arteries was found to be more than double by MDCT when compared with conventional angiography. In MDCT, common trunk of origin of bronchial arteries was noted in 46.4% of patients including two patients who had 2 common trunks in them. In contrast, these common trunks were identified in only 14.3% of

patients by conventional angiography. MDCT detected 3.2 times the number of common trunks detected by conventional angiography.

MDCT was able to identify at least one right and left bronchial artery in all 28 cases, whereas conventional angiography was able to demonstrate right bronchial artery in only 75% of cases and left bronchial artery in only 60.7% of cases.

When a search for bronchial arteries was made on MDCT, it was found that 39% of cases had multiple right bronchial arteries and 64% of cases had multiple left bronchial arteries. Four cases had triple right bronchial artery supply, whereas none cases had triple left bronchial supply. Hypertrophied Right Bronchial artery (more than 1.5mm) was noted in 60.7% cases or 46.5% arteries. Hypertrophied left bronchial artery was noted in 67.9% cases or 43.5% arteries.

The level of origin of bronchial arteries in the Z- axis was clearly depicted in MDCT and was found to be between the D5 and D6 vertebral body level in 91% of right bronchial arteries and 84.8% of left bronchial arteries. In all cases, the bronchial arteries on both sides were noted to originate between D4 and D7 vertebral body level. These results are in agreement with previous reports, which emphasized that more than 70% of bronchial arteries arise from the descending aorta. (60,116,117) Whereas most authors describe the origins of bronchial arteries based on the level or range of thoracic vertebrae (60,116,117), new articles

(21,118) have found that this area of reference is wide and difficult to accurately identify at fluoroscopy. Using trachea as the anatomic reference, it found that all orthotopic right and left bronchial arteries arose at the level of or slightly lower than the tracheal carina, thus facilitating their selective catheterization. The left main bronchial artery was found to be the best reference for locating the origin of bronchial arteries. The ostial position of the bronchial arteies in the axial plane was clearly depicted on MDCT and was found to be between 9 and 1'o clock position in right bronchial arteries. They were most commonly noted between 9 and 10'o clock position (67.3%). When the arteries with common trunk of origin were excluded, 96.4% of right bronchial arteries were found to have origin between 9 and 10'o clock position in the axial plane. Intercostobronchial origin of right bronchial artery was noted in 89.3% of right bronchial arteries. No left bronchial artery had an intercostobronchial origin.

The left bronchial arteries had their ostia between 9 and 2'o clock position, with 84.8% of left bronchial arteries arising between 11 and 1'o clock position. When the common trunk of origin of bronchial arteries was excluded, this figure rose to 87.1%. These findings confirm that the majority of right bronchial arteries arise in the medial wall of the descending aorta, whereas most left bronchial arteries arise in the anterior wall of the descending aorta (18,21,61)

The right intercostobronchial arteries had their origin between D5 and D6 level in 92% cases and their ostial position was between 9 and 10'o clock in 96% of cases. The common trunk of origin of bronchial arteries was noted to have origin between D5 and D6 level in 86.7% and were found to have their ostia between 11 and 1'o clock positon in 80% of arteries.

Regarding the nonbronchial systemic arteries, it was found that these were more common on the left side (41 on left compared with 23 on right). Because recurrent hemoptysis after a successful bronchial artery embolization may be related to the presence of a nonbronchial systemic arterial supply, one should emphasize the usefulness of its depiction with CT angiography prior to the second embolization session. Of particular importance is the subclavian artery and its branches (most commonly, the internal mammary artery) for upper-lobe bleeding and the inferior phrenic artery for lower-lobe bleeding (2,13,14,16,17,18, 120,30). However, numerous additional vessels may give rise to a nonbronchial systemic arterial supply to the lung, such as the branches of the axillary arteries, the intercostals arteries, or the hepatic and gastric arteries (9,11,126). The internal mammary artery was found to be supplying lung lesions when the adjoining pleural thickness was more than 3mm. The size of the internal mammary artery was also assessed in all patients and it was found that a size more than 3mm diameter was associated with supply to the lung lesions. The sensitivity and

specificity for this cut off of 3mm of internal mammary artery was 100% and this was found to be statistically highly significant. The average size of the hypertrophied internal mammary arteries was found to be 3.8mm. Similarly, the inferior phrenic arteries were found to be hypertrophied and supplying lung lesions when a lower lobe lung lesion was associated with adjacent pleural thickening. A cutoff of 2mm for the inferior phrenic arteries had a sensitivity of 75% and specificity of 91.67%. The negative predictive value was high (95.6%) This cut off of diameter for inferior phrenic artery was also found to be statistically significant.

The ostial position of intercostals arteries on both side was also checked in all cases since they are one of the most common nonbronchial systemic arteries. It was found that the ostial position of both normal and pathologic intercostal arteries between D4 and D7 level was very consistent, between 9 and 10'o clock position for all right intercostals arteries and between 6 and 7'o clock position for all left intercostals arteries.

CT angiographic findings enabled direct selective catheterization of abnormal nonbronchial systemic artery in the vicinity of the bleeding site in 8 patients. These results suggest that multi–detector row helical CT angiography can help in the planning of a focused and efficient nonbronchial systemic artery embolization, as was recently reported with single– detector row CT (20,21).

Consequently, thoracic aortography, an invasive procedure still recommended by many authors to improve the detection of arteries contributing to hemoptysis (2,126, 63) should be replaced with CT angiography. (21)

Even though a direct comparison cannot be made in this study since it was a life threatening disease and it is against ethics to blind the study, when MDCT and conventional angiography were compared for the detection efficiency of bronchial and nonbronchial systemic arteries, it was found that the detection efficiency of MDCT was clearly better for the detection of bronchial and nonbronchial systemic arteries on both sides and the difference was found to be statistically significant. Because the most dreaded consequence of a bronchial artery embolization is inadvertent occlusion of spinal arteries, we included the search for an anterior spinal artery on curved MIPs of the cervicothoracic junction in all patients. The lack of identification of this vessel on CT and/or conventional angiograms in these patients precludes any conclusion regarding the accuracy of CT angiography in depicting this important collateral, which was present in about 5% of patients. (21,122)

CONCLUSION

This study has showed that MDCT is an important diagnostic tool in the evaluation of hemoptysis, It aids in evaluation of the lung parenchyma, helps to diagnose the disease process, estimates the volume of lung parenchymal loss and detects pathologic bronchial and nonbronchial arteries. The anatomy of the bronchial arteries has been proved to be clearly depicted in this study. A new mode of reference for the axial localization of bronchial arteries by the clock method was used in this study and found to be very helpful in the selective catheterization of bronchial arteries. For z-axis (cranio-caudal) localization, it was found that the vertebral body level is a good reference level for comparison, but the use of the left main bronchus as a reference level was found to be more useful for the interventional radiologist.

All the bronchial arteries were found to arise between D4 and D7 level and these arteries followed expected normal course. Hence the definition of orthotopic bronchial arteries can include those arising from D4 and D7 level also instead of just D5-D6 level. The ostia of right bronchial artery was found to be commonly between 9 and 10’o clock position and left bronchial artery between 11 and 1’o clock position. The intercostal arteries were also found to have a fixed ostial

position. These data may be extremely useful for the interventional radiologist and helps to avoid thoracic aortography.

The predictors for nonbronchial supply like a significant pleural thickening (3mm and above), hypertrophied internal mammary artery (3mm and above) and inferior phrenic artery (2mm and above) have been validated by this study. Multiple nonbronchial systemic arteries were detected in this study with as many as 12 arteries in a single patient and this indicates the need for a search for such arteries prior to embolotherapy in order to prevent recurrent hemoptysis. With the multitude of uses and superiority over conventional angiography, MDCT has proved to be the single best pre embolotherapy investigative modality and can be considered as the gold standard for evaluation of life threatening hemoptysis. This study will aid to evolve a new protocol for evaluation of life threatening hemoptysis, which is very common in our country because of tuberculosis and has the potential to save many lives.

ANNEXURES

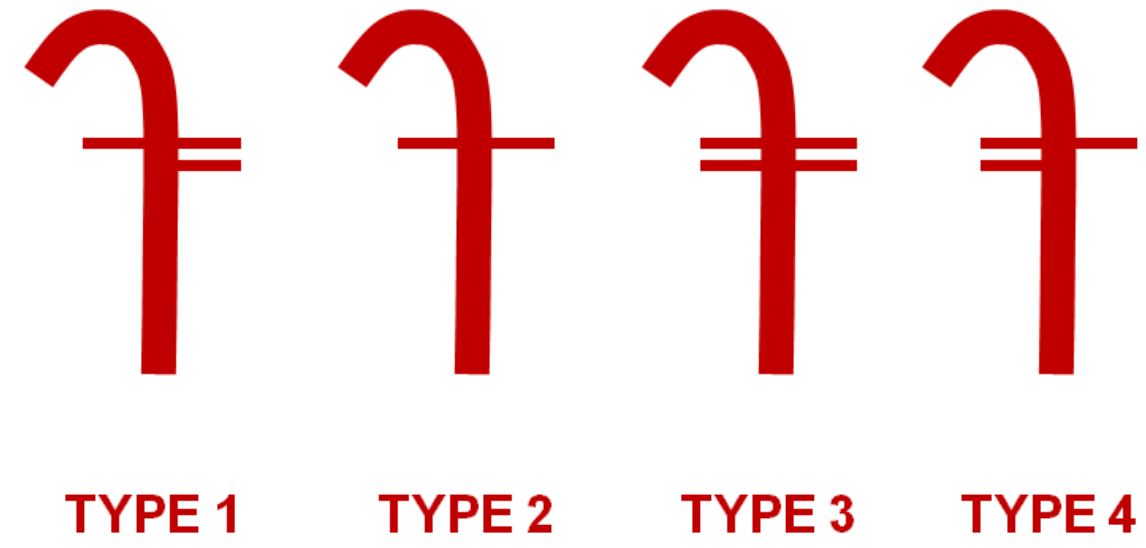


FIGURE.1 CAULDWELL'S CLASSIFICATION OF BRONCHIAL ARTERIES

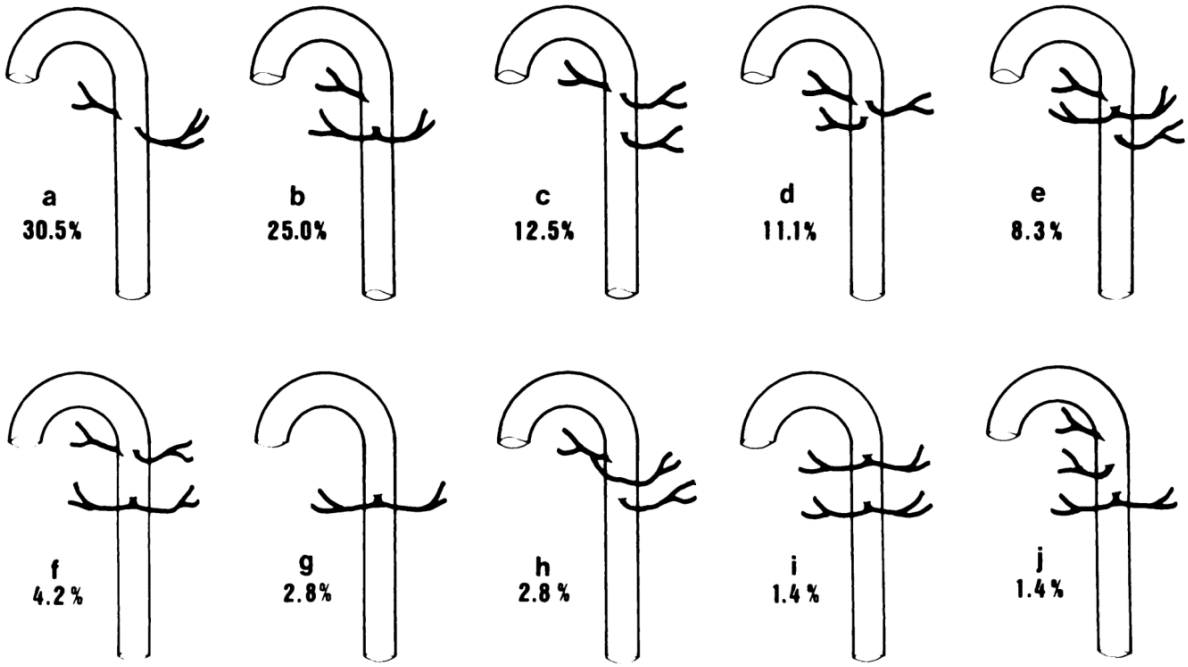


FIGURE.2 UFLACKER'S TEN TYPES OF BRONCHIAL ARTERIES

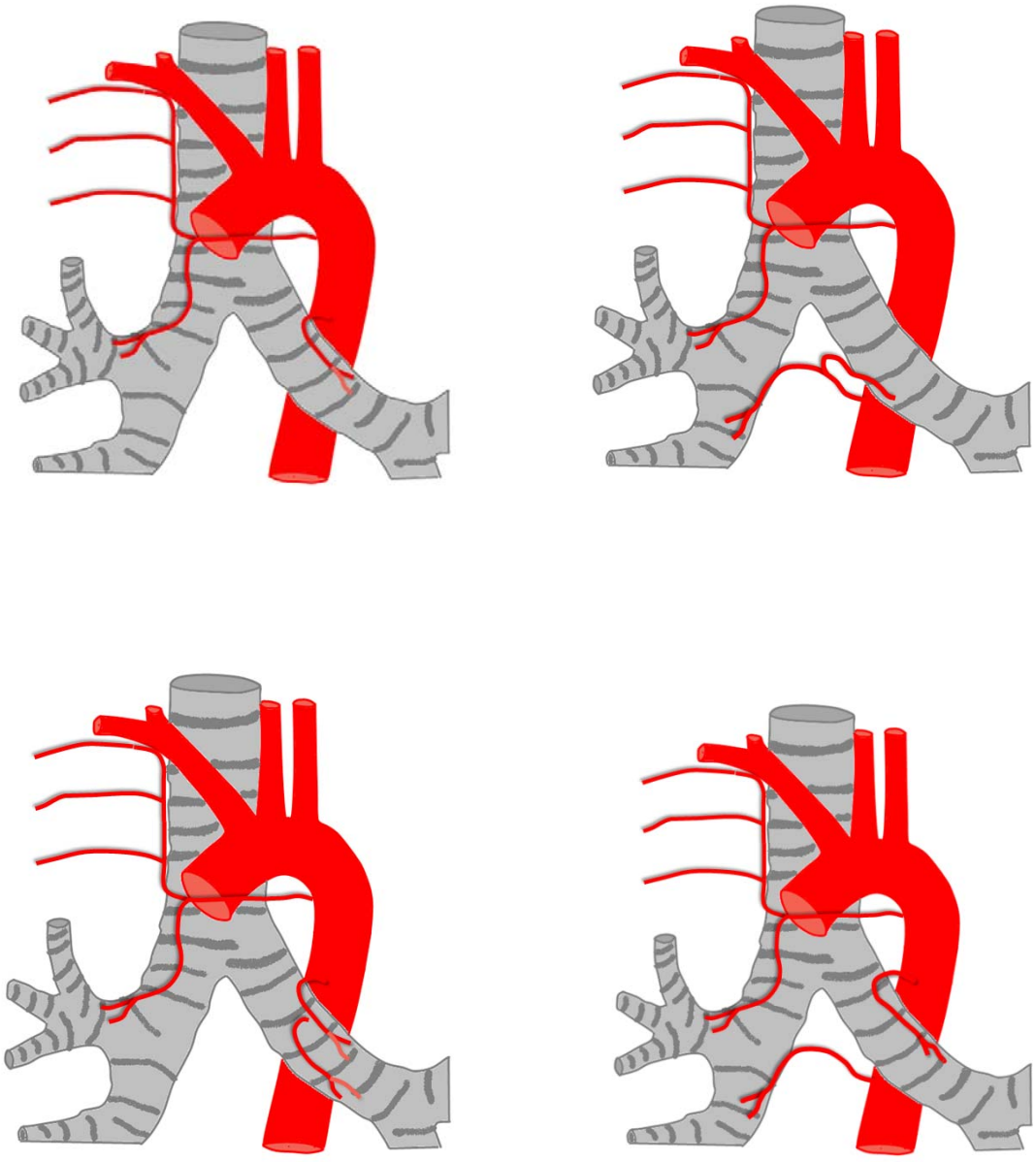


FIGURE.3 THE FOUR MOST COMMON TYPES OF BRONCHIAL ARTERIES NOTED IN UFLACKER'S STUDY

FIGURE. 4 64 DETECTOR CT MACHINE

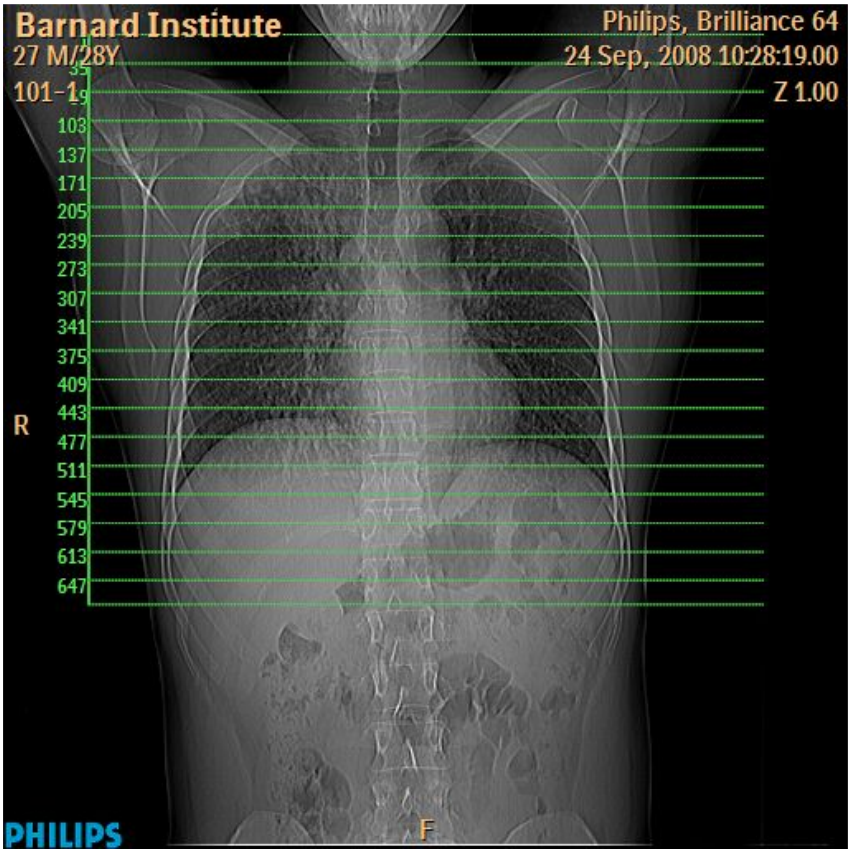


FIGURE. 5 SCANNING VOLUME

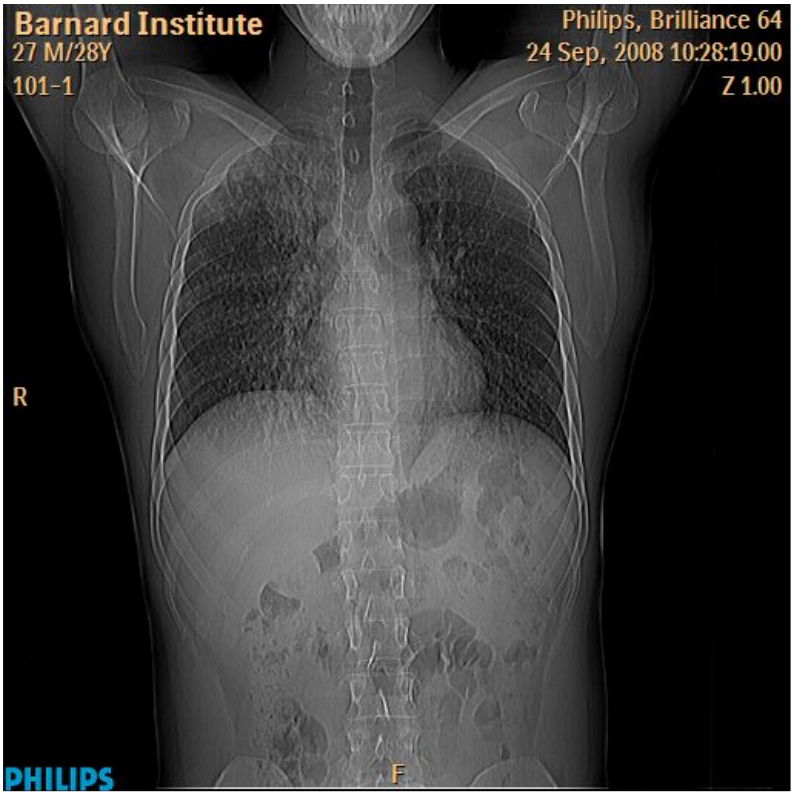


FIGURE. 6 SCANOGRAM

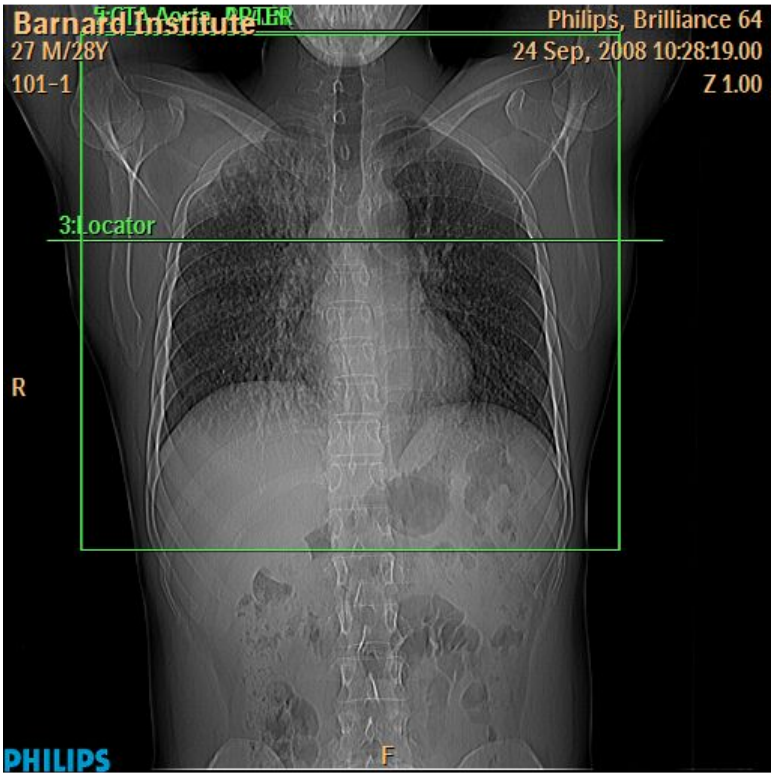


FIGURE. 7 LOCATOR FOR ROI

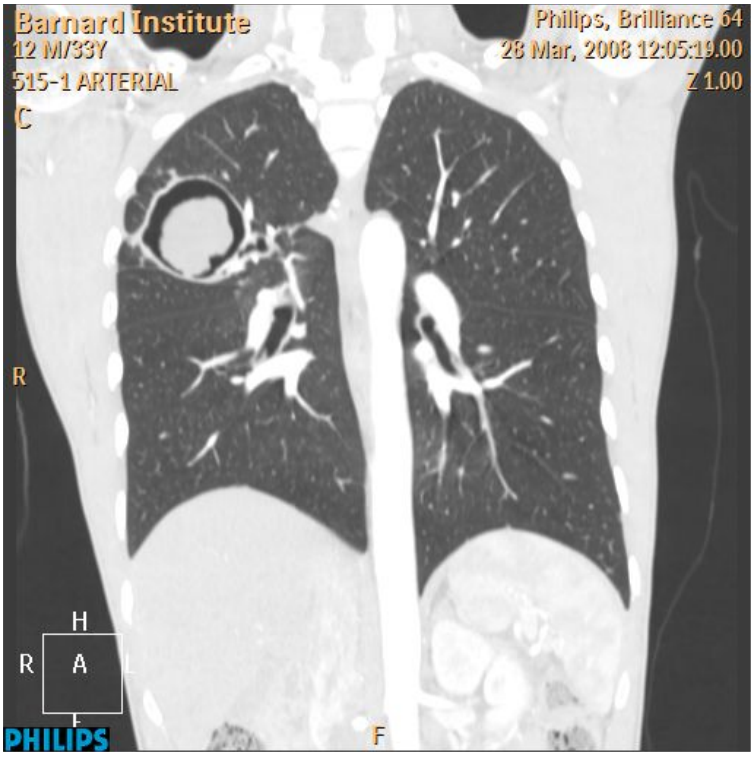


FIGURE.8 ASPERGILLOMA IN AN OLD TUBERCULOUS CAVITY

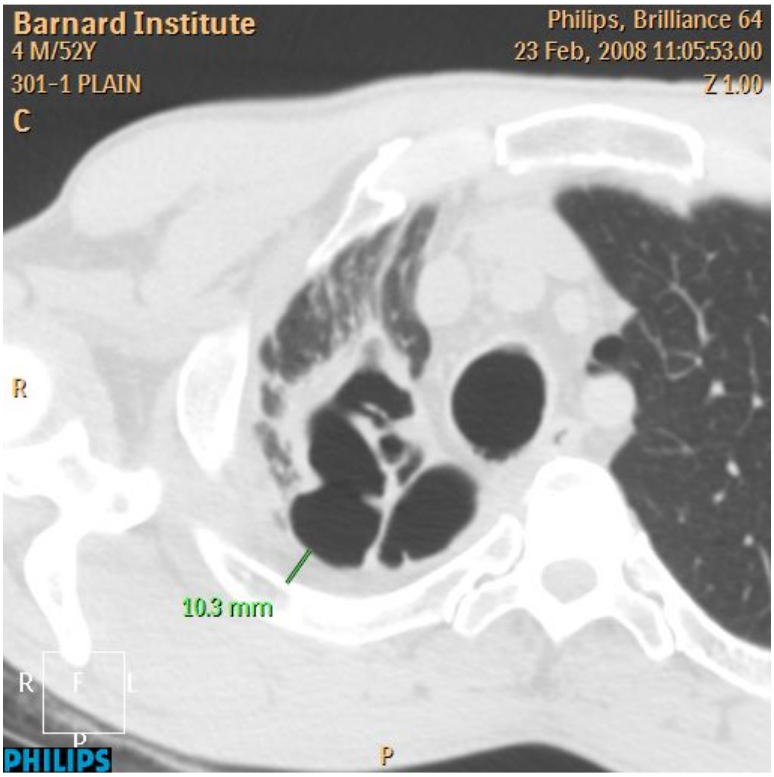


FIGURE. 9 PLEURAL THICKENING MORE THAN 3MM CONSIDERED TO BE SIGNIFICANT

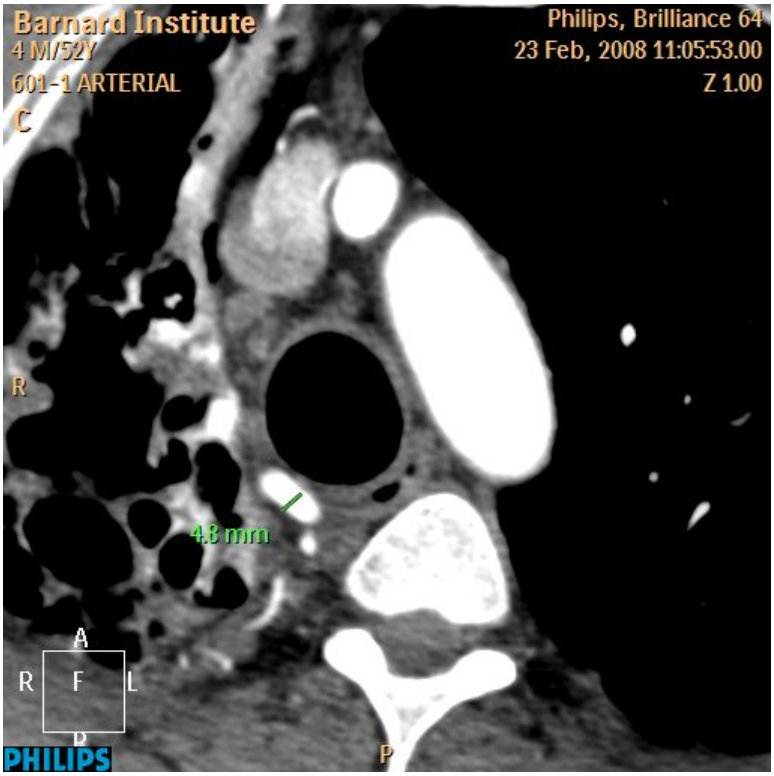


FIGURE. 10 HYPERTROPHIED VESSEL OF 4 MM DIA

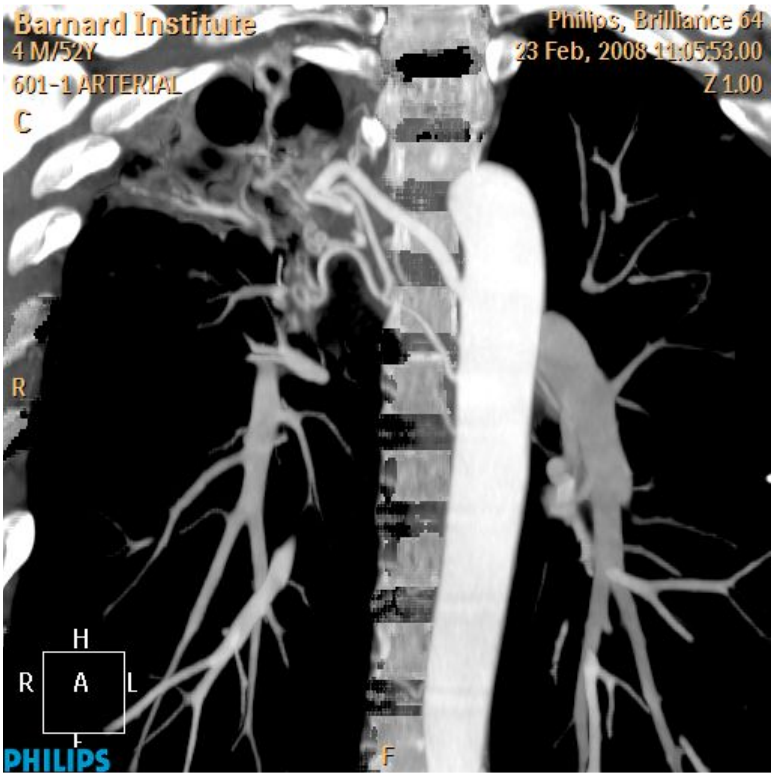


FIGURE. 11 TORTUOUS COURSE OF BRONCHIAL ARTERY IN CORONAL VIEW

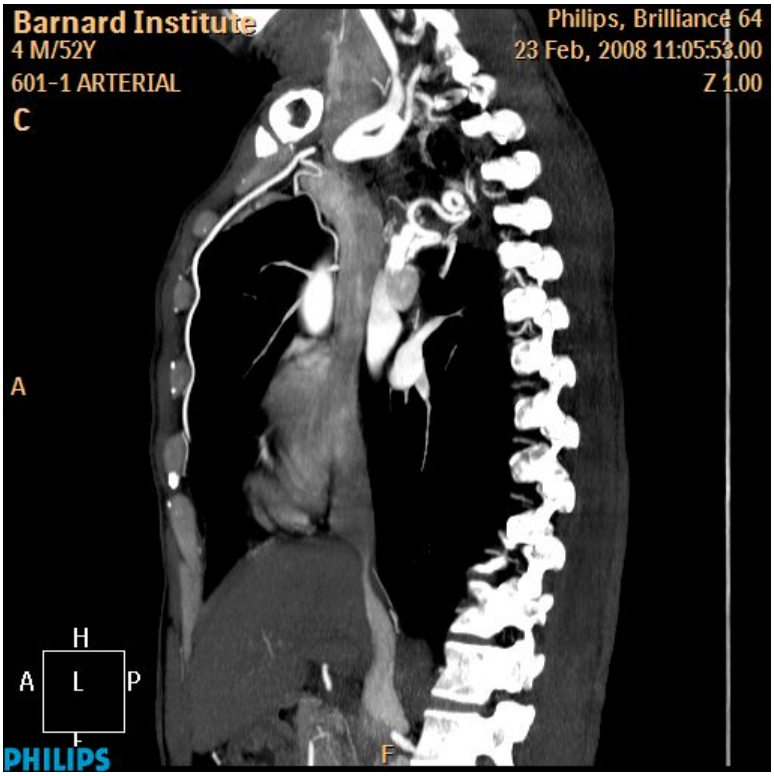


FIGURE. 12 TORTUOUS COURSE OF BRONCHIAL ARTERY IN SAGITAL VIEW

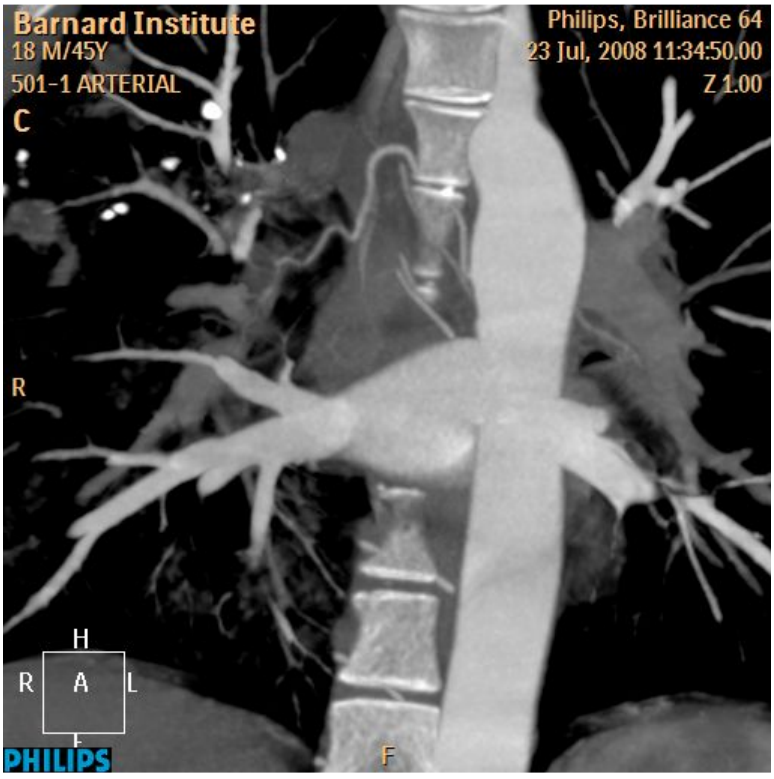


FIGURE 13 BRONCHOPULMONARY SHUNTING

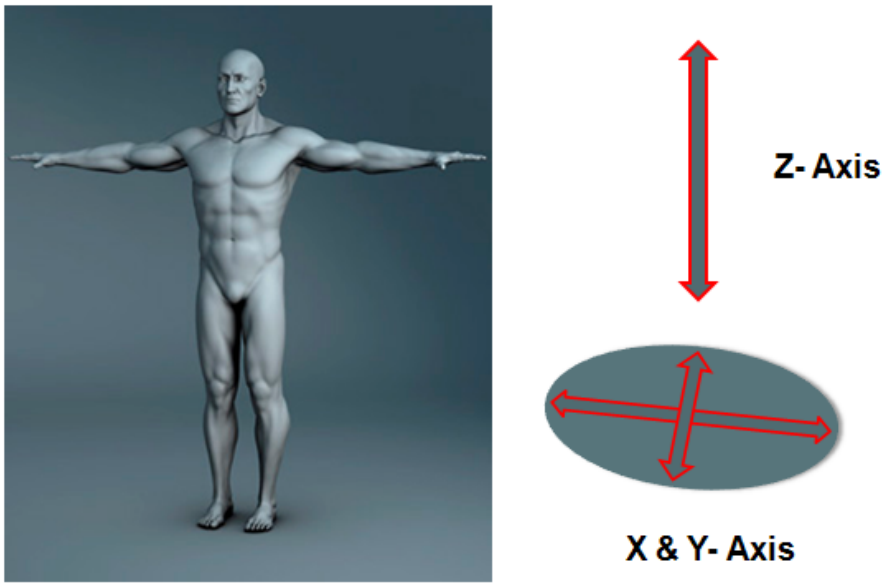


FIGURE. 14 LOCALISATION OF ORIGIN OF BRONCHIAL ARTERY IN 3 PLANES

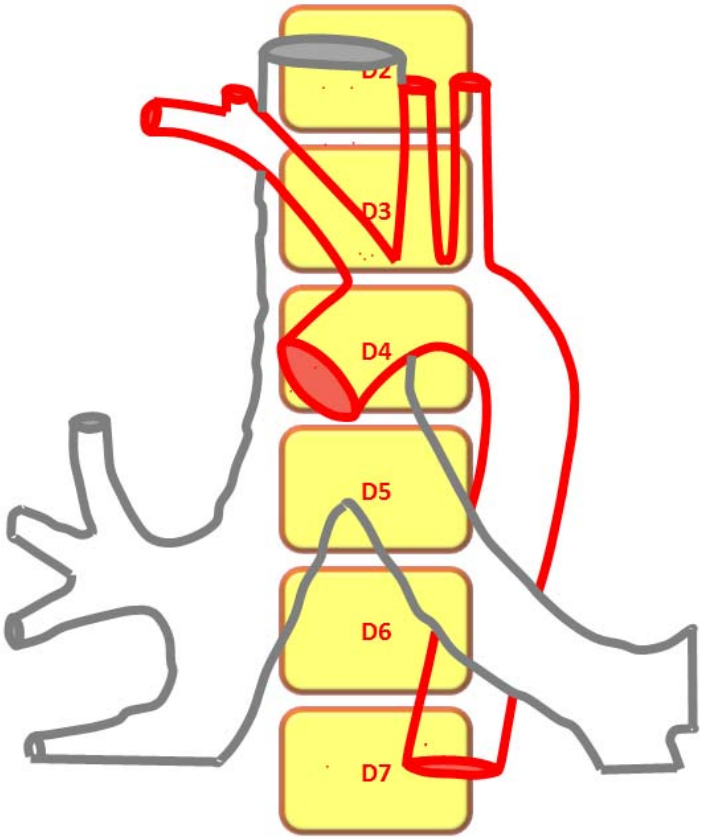


FIGURE. 15 REFERENCES FOR LOCALIZATION OF ORIGIN OF BRONCHIAL ARTERY IN Z – AXIS - THE CARINA, LEFT MAIN BRONCHUS AND THE VERTEBRAL BODY LEVEL

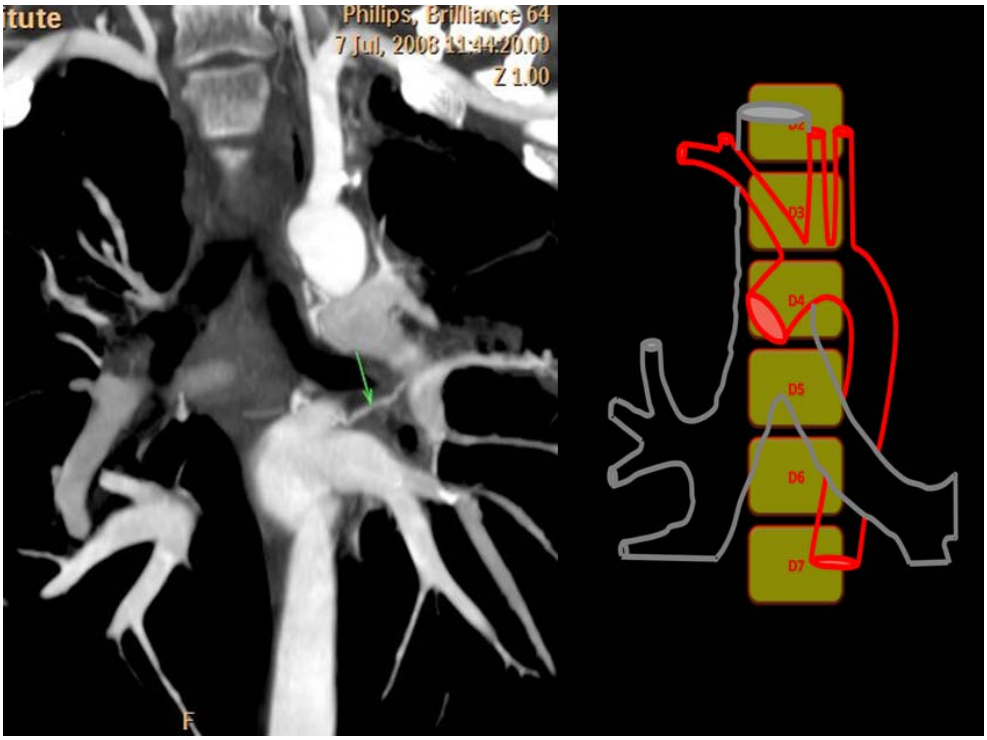


FIGURE.16 USAGE OF Z-AXIS REFERENCE LEVEL IN CORONAL MIP RECONSTRUCTION

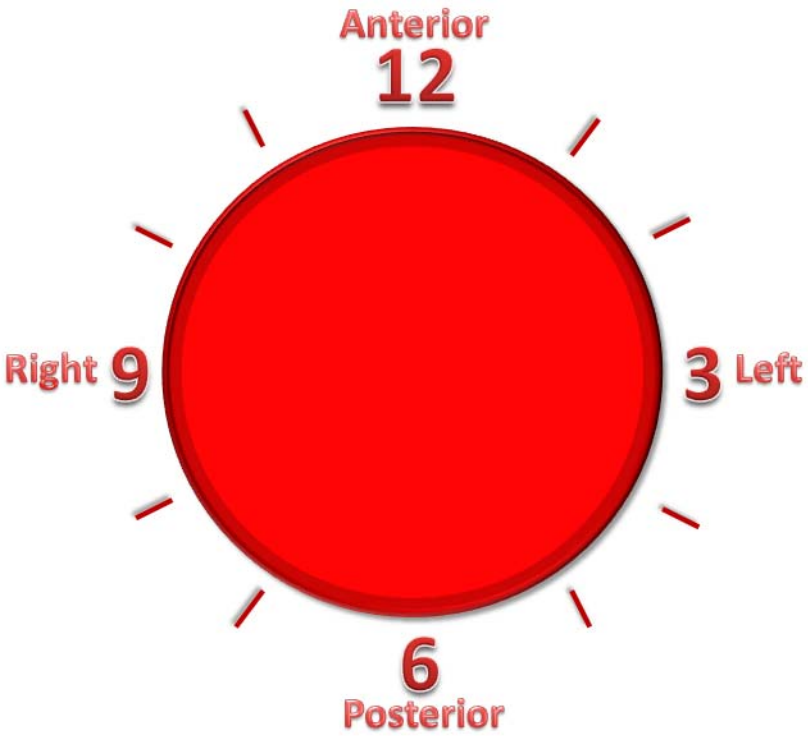


FIGURE. 17 CLOCK METHOD TO LOCATE THE ORIGIN OF BRONCHIAL ARTERY IN X AND Y AXIS

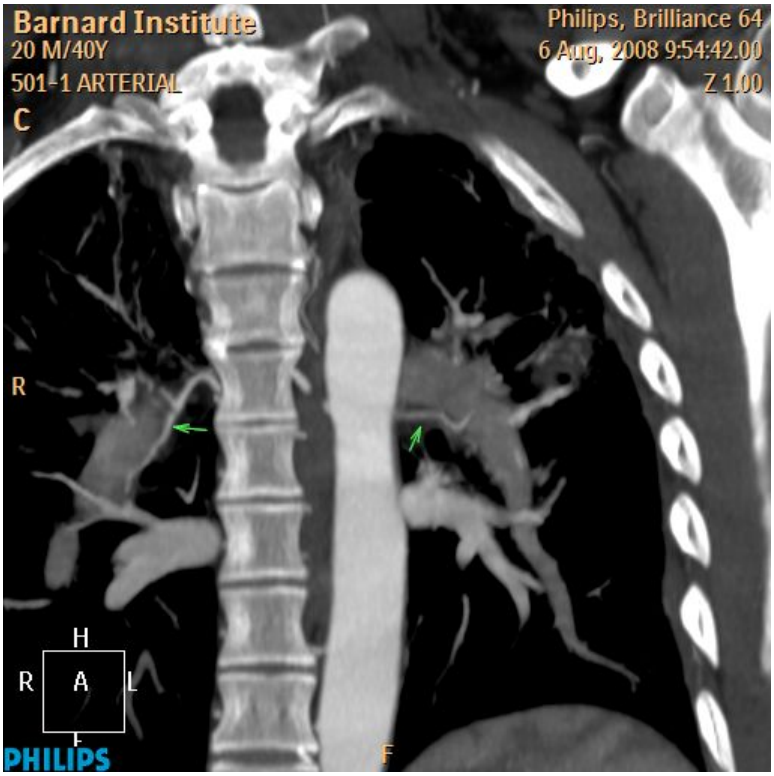


FIGURE. 18 CORONAL MIP IMAGE

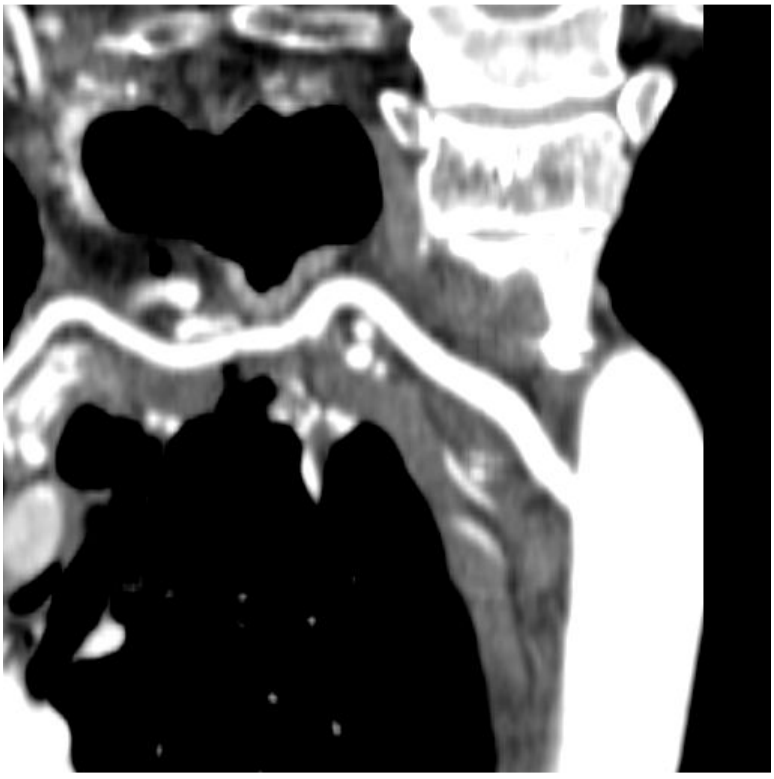


FIGURE. 19 CURVED MPR TO SHOW INTRA AND EXTRA PULMONARY COURSE

FIGURE. 20 3D SHADED SURFACE DISPLAY

FIGURE. 21 ANGIOFRAPHY SUITE

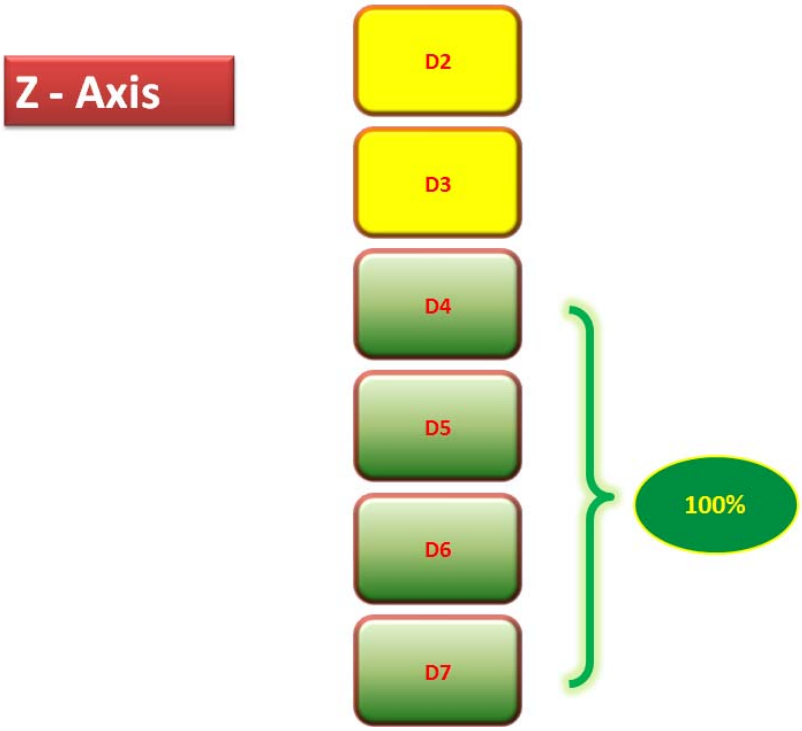


FIGURE. 22 Z-AXIS LOCALISATION OF ALL BRONCHIAL ARTERIES

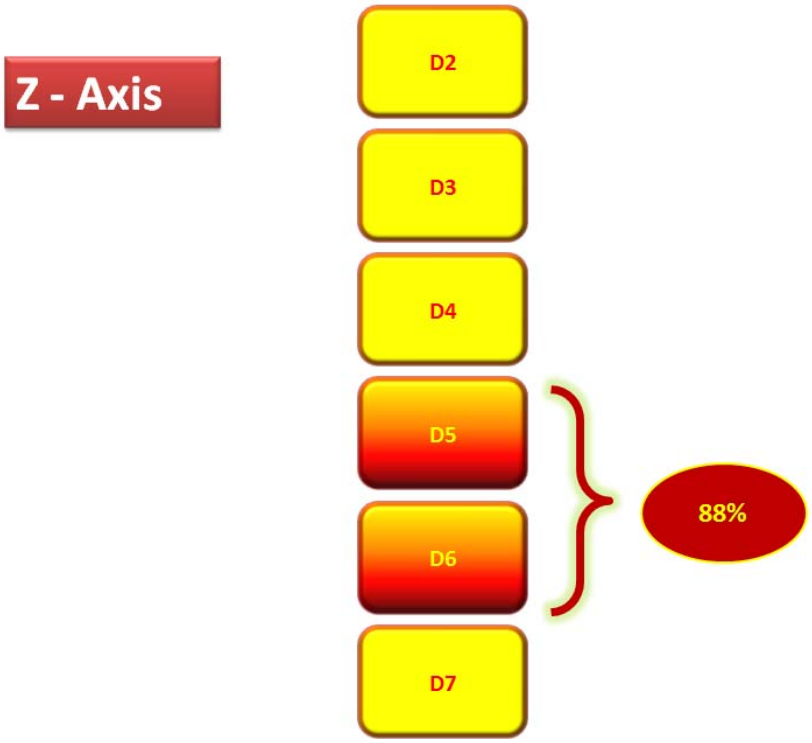


FIGURE. 23 COMMON LOCATION OF BRONCHIAL ARTERIES ON Z-AXIS

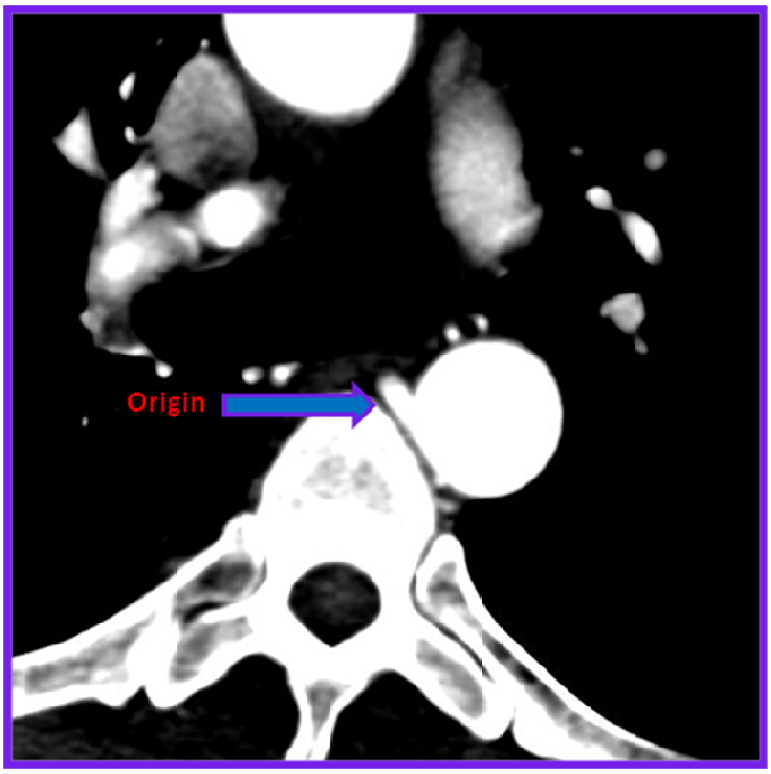


FIGURE. 24 AXIAL MIP IMAGE SHOWING RIGHT BRONCHIAL ARTERY ORIGIN AT D4 LEVEL – 9’ 0 CLOCK POSITION

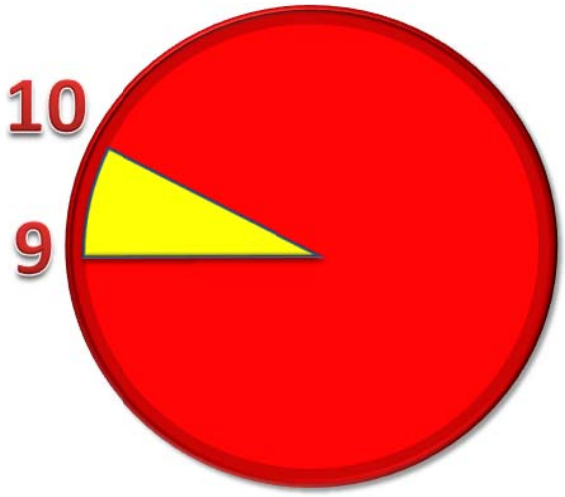


FIGURE. 25 MOST COMMON OSTIAL POSITION (96%) OF RIGHT BRONCHIAL ARTERIES

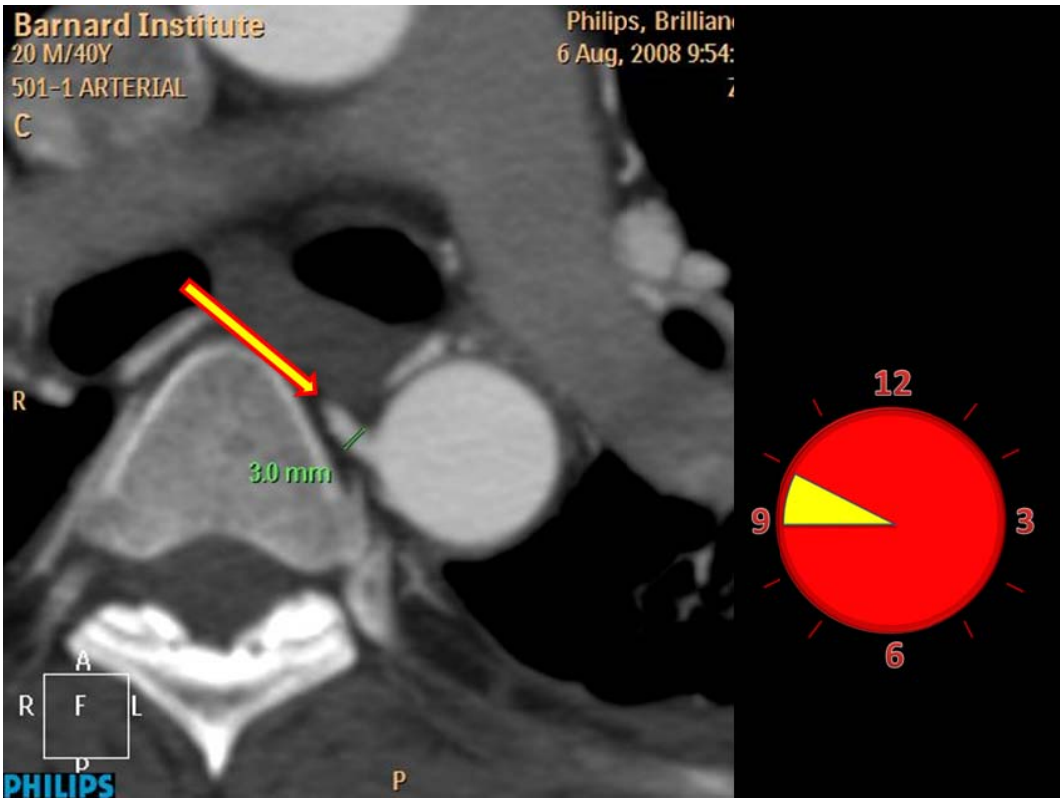


FIGURE. 26 LOCALISATION OF RIGHT BRONCHIAL ARTERY IN X-Y AXIS

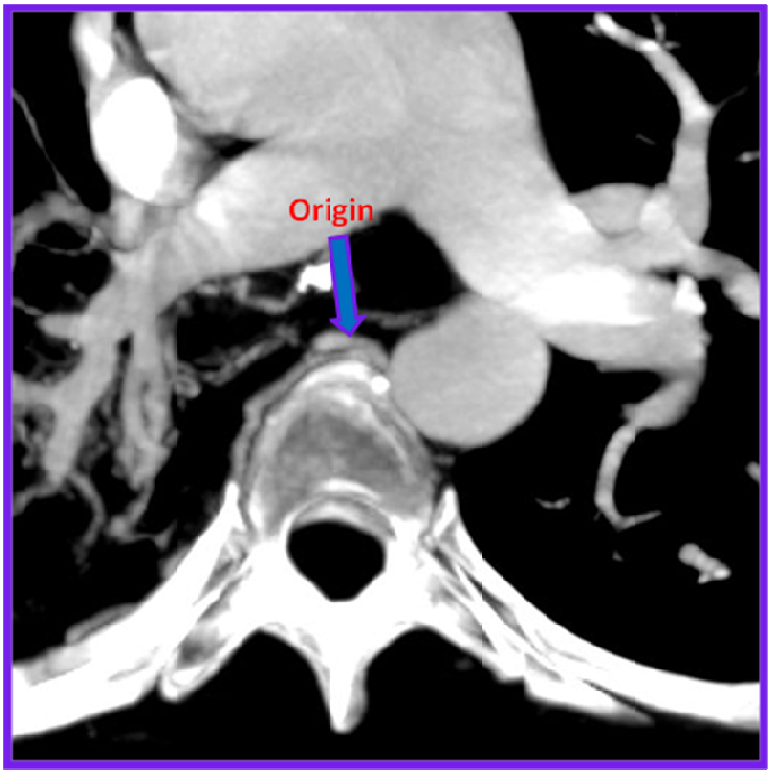


FIGURE.27 AXIAL MIP IMAGE REVEALING RIGHT INTERCOSTO BRONCHIAL ARTERY ORIGIN AT D5 LEVEL – 9’ 0 CLOCK POSITION

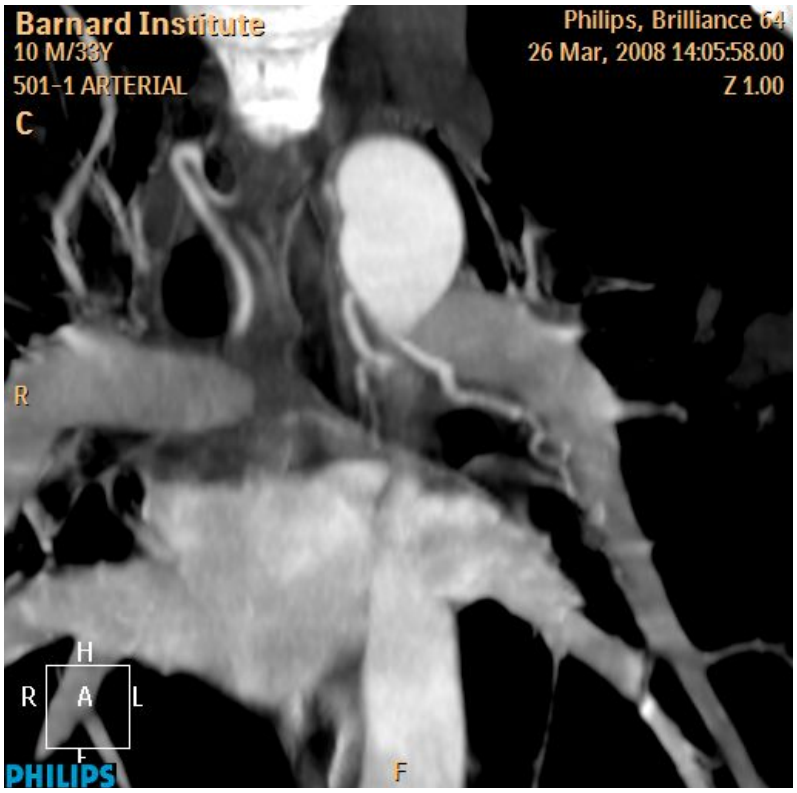


FIGURE. 28 CORONAL MIP IMAGE SHOWING COURSE OF LEFT BRONCHIAL ARTERY ALONG SUPERIOR MARGIN OF LEFT MAIN BRONCHUS

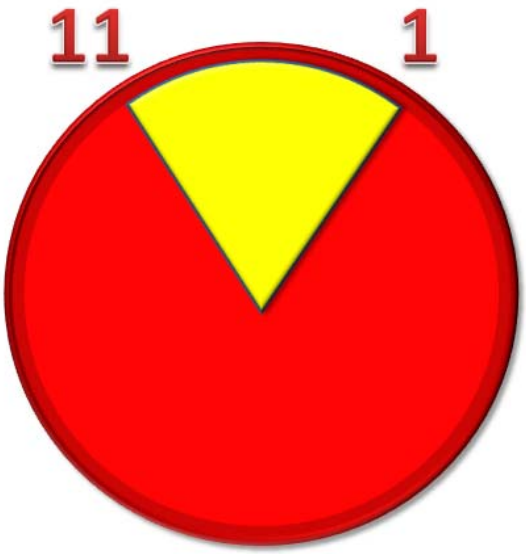


FIGURE. 29 MOST COMMON OSTIAL POSITION (87%) OF LEFT BRONCHIAL ARTERIES

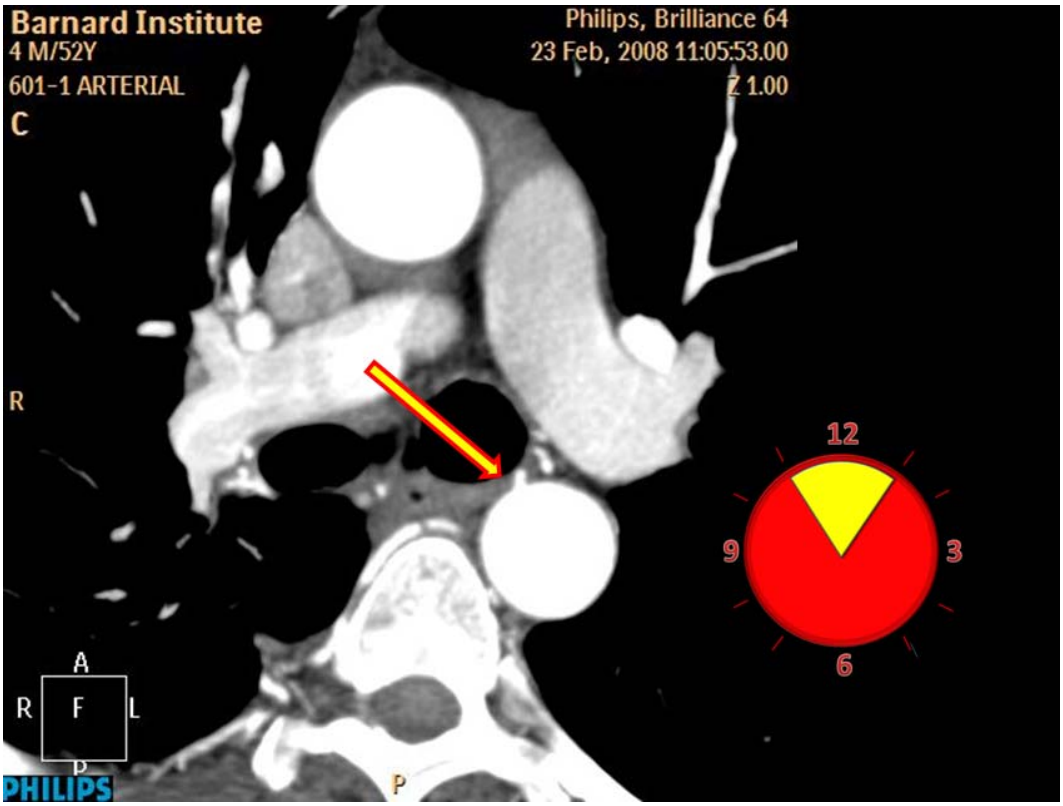


FIGURE. 30 LOCALISATION OF LEFT BRONCHIAL ARTERY IN X-Y AXIS

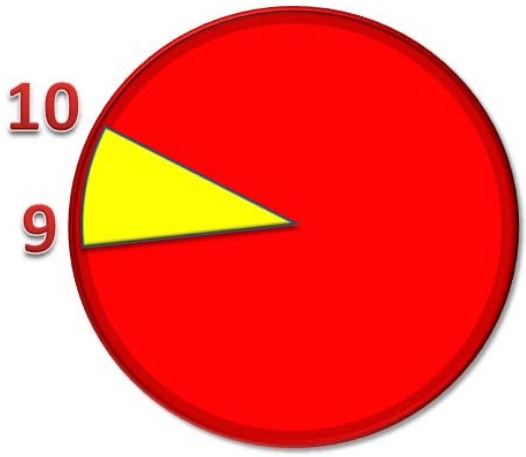


FIGURE. 31 ORIGIN OF RIGHT POSTERIOR INTERCOSTAL ARTERY BETWEEN D4 TO DL LEVEL (100%)

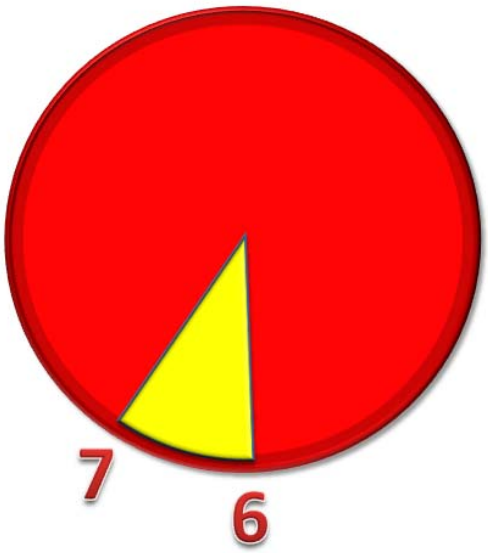


FIGURE. 32 ORIGIN OF LEFT POSTERIOR INTERCOSTAL ARTERY BETWEEN D4 TO DL LEVEL (100%)

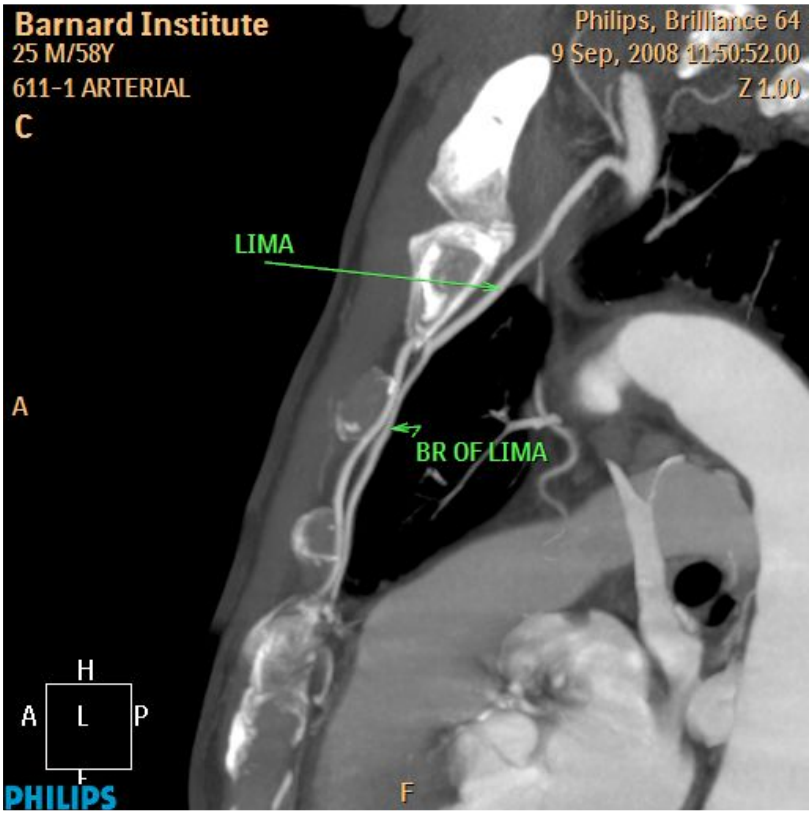


FIGURE. 33 INTERNAL MAMMARY ARTERY

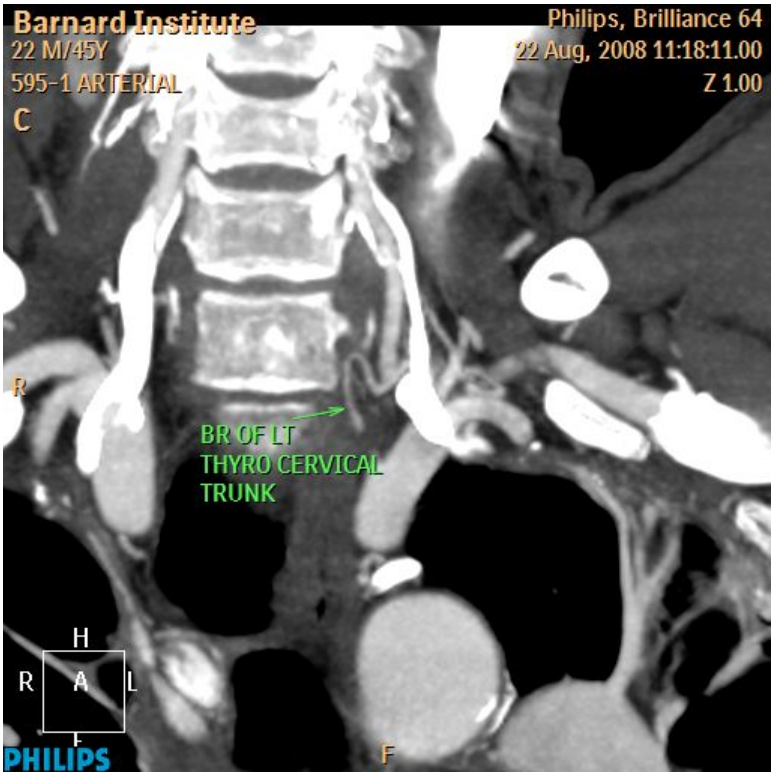


FIGURE. 34 THYROCERVICAL TRUNK

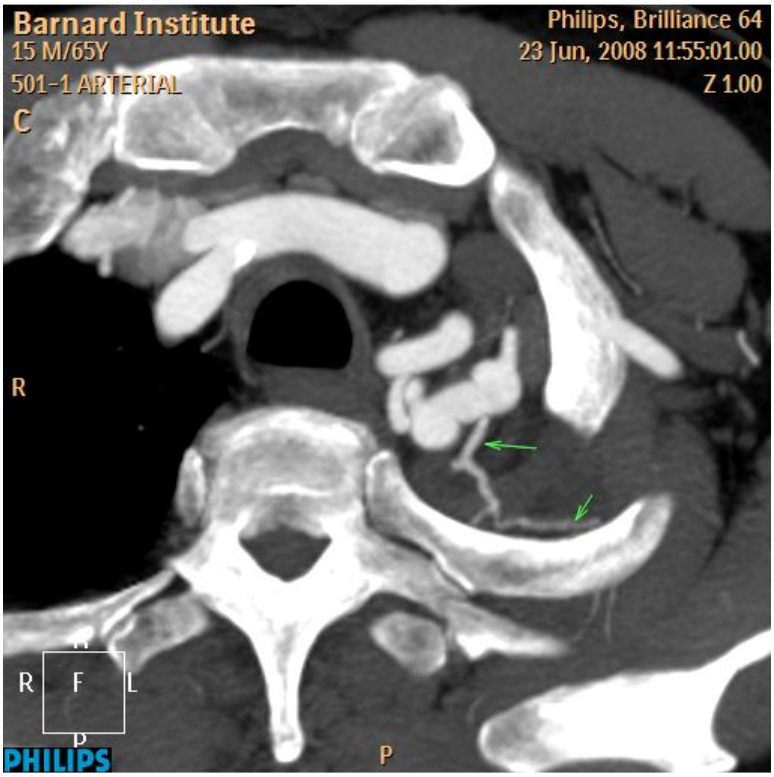


FIGURE. 35 SUBCLAVIAN ARTERY

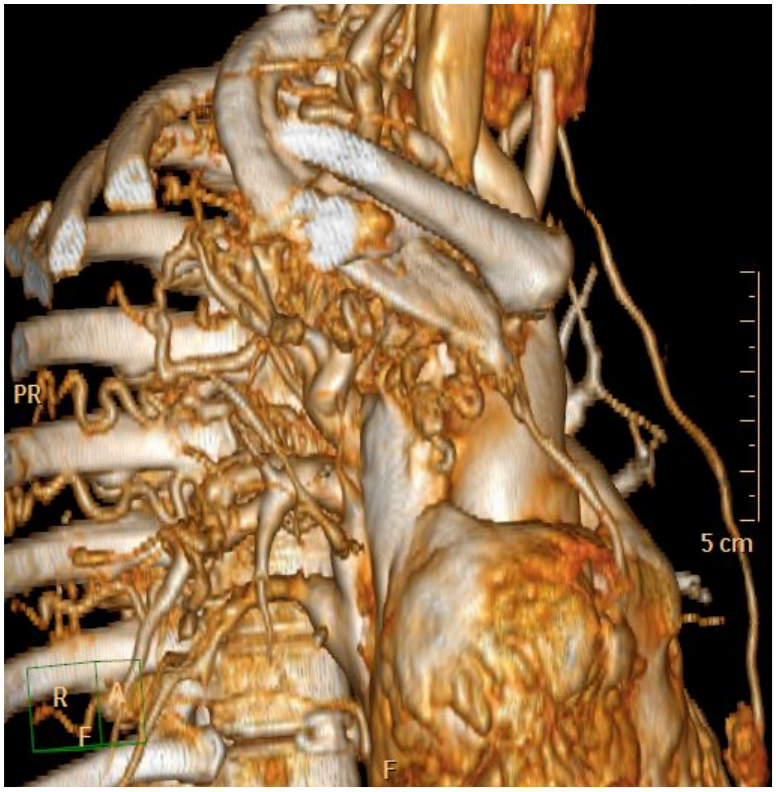


FIGURE. 36 INTERCOSTAL ARTERIES

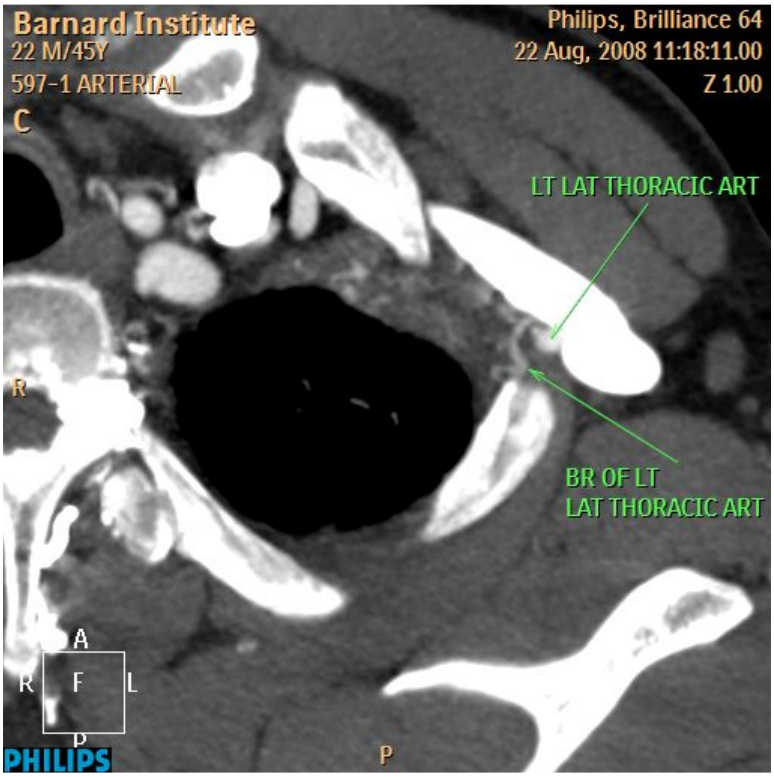


FIGURE. 37 LATERAL THORACIC ARTERY

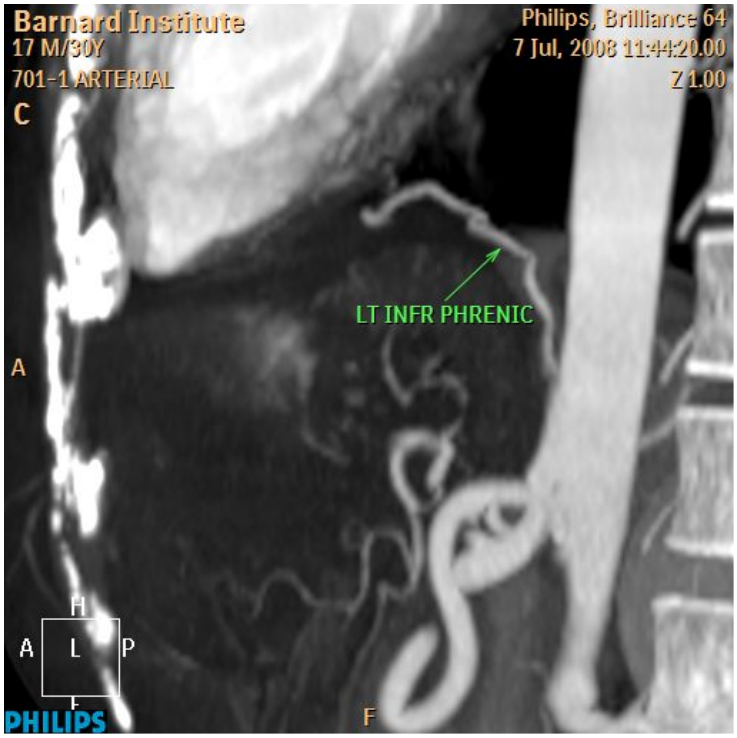


FIGURE. 38 INFERIOR PHRENIC ARTERY

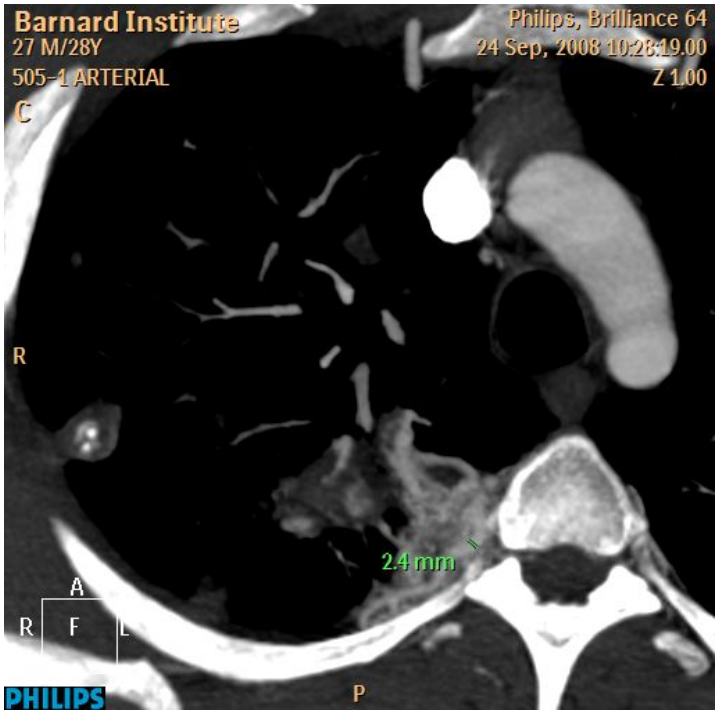


FIGURE. 39 HYPERTROPHIED RIGHT INTERCOSTAL ARTERY WITH PARENCHYMAL STAINING

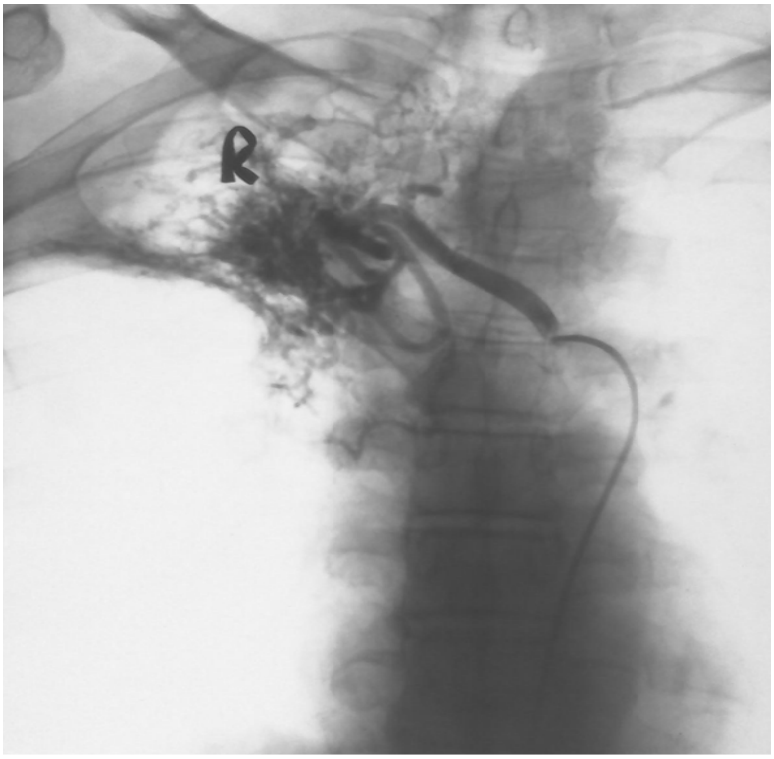


FIGURE. 40 RIGHT BRONCHIAL ARTERY

FIGURE. 41 SUPPLY FROM HYPERTROPHIED RIGHT INTERCOSTOBRONCHIAL ARTERY

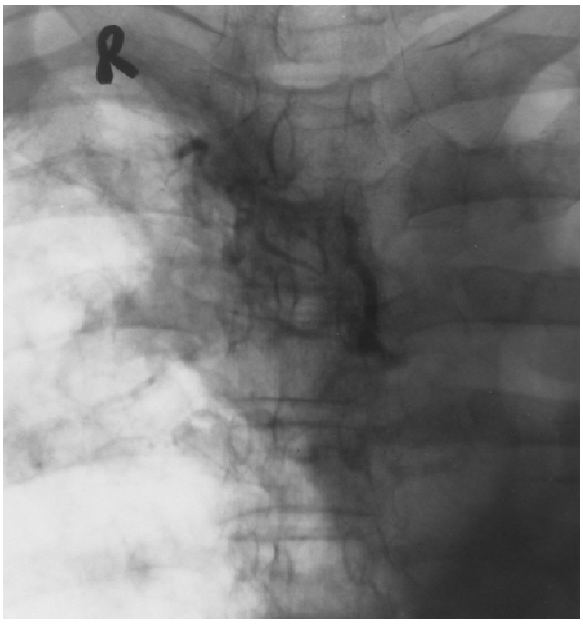


FIGURE. 42 STANDING COLUMN OF CONTRAST POST EMBOLIZATION

FIGURE. 43 PARENCHYMAL STAINING NOTED ON INJECTION OF CONTRAST INTO RIGHT INTERCOSTOBRONCHIAL ARTERY

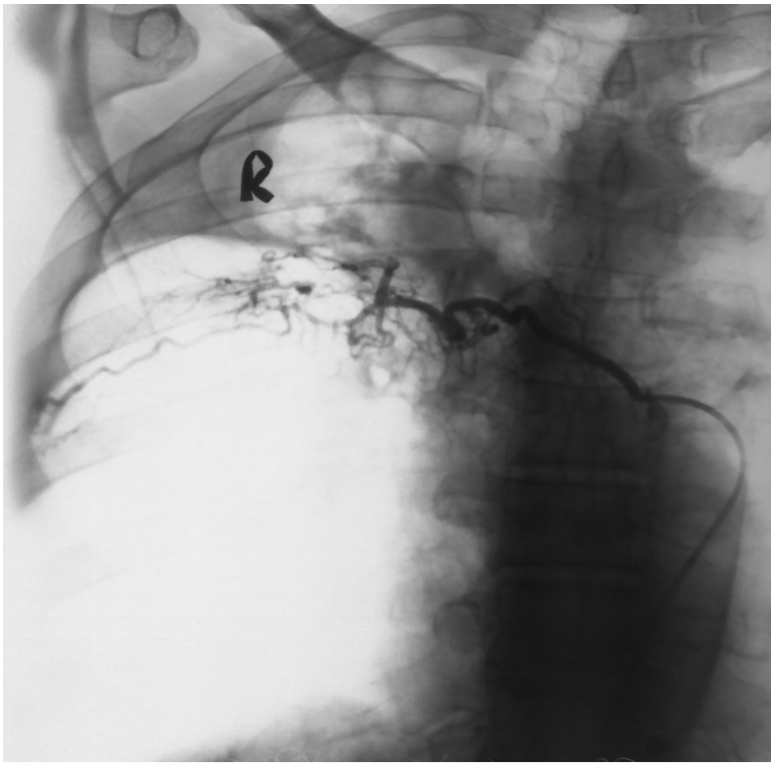


FIGURE. 44 RIGHT FOURTH INTERCOSTAL ARTERY

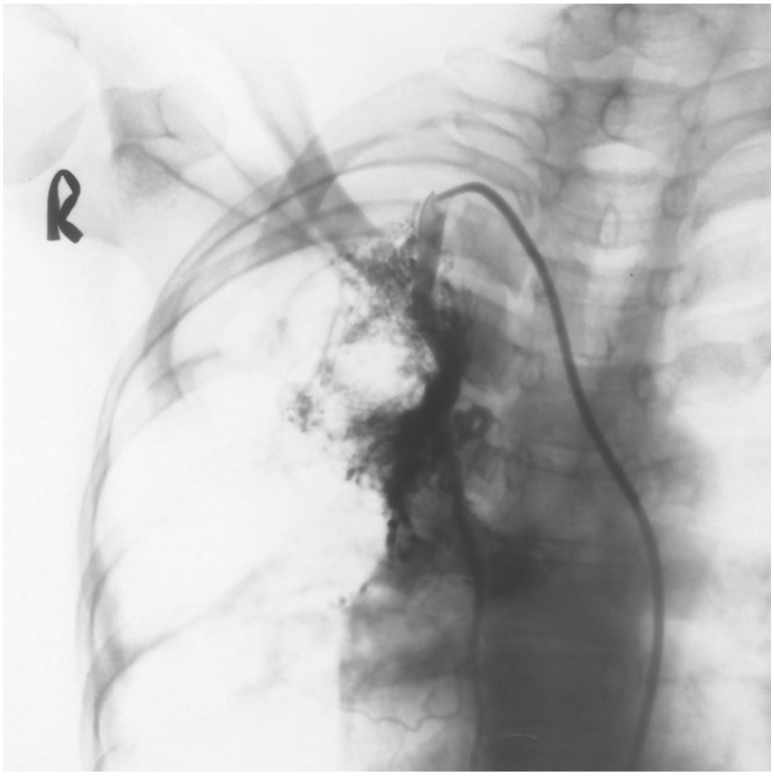


FIGURE. 45 RIGHT INTERNAL MAMMARY ARTERY

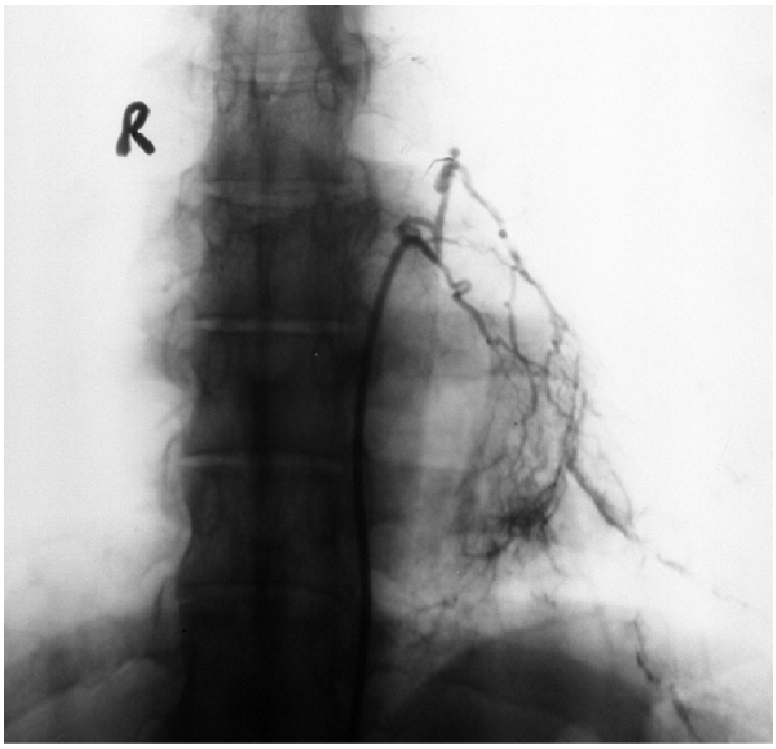


FIGURE. 46 SUPPLY FROM LEFT BRONCHIAL ARTERY

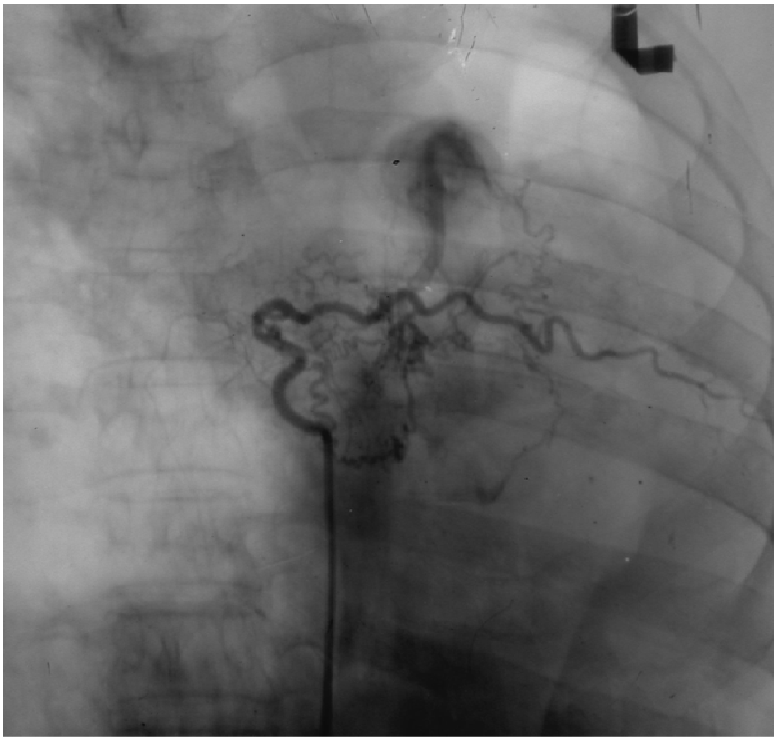


FIGURE. 47 BRONCHO PULMONARY SHUNT

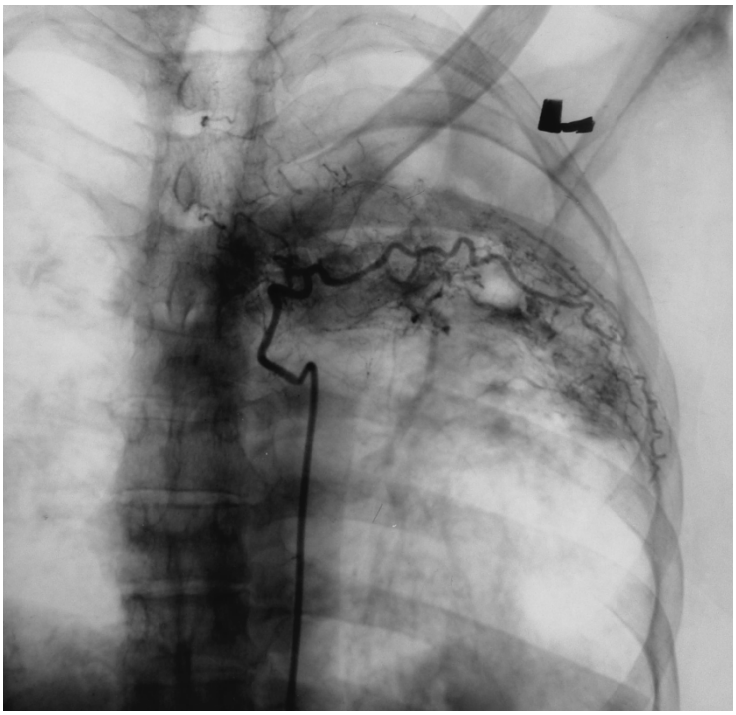


FIGURE. 48 PARENCHYMAL STAINING FROM HYPERTROPHIED LEFT INTERCOSTAL ARTERY

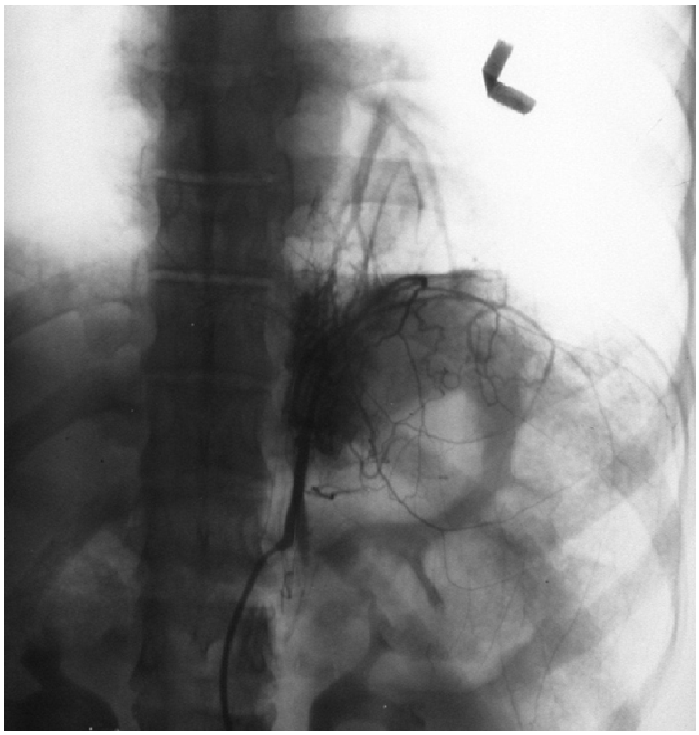


FIGURE. 49 HYPERTROPHIED LEFT PHRENIC ARTERY

PROFORMA

Bleeding Vessels in Life Threatening Hemoptysis: Comparison of 64 Detector Row CT Angiography with Conventional Angiography Prior to Endovascular Management

NAME: **PT. ID:**

AGE/SEX: **WT:** **KG** **DATE OF EVALUATION:**

HOSPITAL: **WARD** **HOSP. ID:**

ADMITTED ON: **DISCHARGED ON:**

HOME ADDRESS: **PH. NO:**

PRESENT HISTORY:

Hemoptysis –

No. of Episodes –

Volume of Hemoptysis (Approx) -

Physician Opinion of Threat to Life –

Other Symptoms -

ATT: Regime -

Date of Commencement - **Date of Completion -** **Duration-**

CONSENT

I do hereby give consent for the above mentioned study. The risks involved were clearly explained to me.

(Signature) Relation:

PAST HISTORY:

INVESTIGATIONS:

Sputum - **Date:**

CT – **Date:**

Bronchoscopy – **Date**

CXR - **Date**

CT PROTOCOL: **Date -**

Contrast Material – (350mg/dL)

Rate – 5ml / Sec

Canula – 18 G

Commencement of Scan – Phase of peak arterial enhancement. Automatic trigger with preset of 100 HU at Arch of Aorta

Factors - 140 kV, 70 to 120 mAs

Rotation Time - 0.5 Sec

Collimation – 0.75 mm

Pitch – 0.5

Scan Duration –

Height of Volume Scanned -

Complications -

CT FINDINGS:

Bronchial Vessels Identified –

Site of Origin of Vessels –

Location of Ostia –

Extra pulmonary Course of Vessel –

Intra pulmonary Course of Vessel –

Width of Vessel –

Tortuosity –

Parenchymal Staining –

Systemic – Pulmonary Arterial Shunting -

Contrast Extravasation at points of bleeding –

Identification of Spinal Arteries -

ANGIOGRAPHY METHODOLOGY: **Date -**

Time interval between CT and Angio -

Approach –

Contrast Injected –

Volume of Contrast Used -

Time taken for Study –

Complications -

ANGIOGRAPHY FINDINGS:

Bronchial Vessels Identified –

Site of Origin of Vessels –

Location of Ostia –

Extra pulmonary Course of Vessel –

Intra pulmonary Course of Vessel –

Width of Vessel –

Tortuosity –

Parenchymal Staining –

Systemic – Pulmonary Arterial Shunting -

Contrast Extravasation at points of bleeding –

Identification of Spinal Arteries -

EMBOLISATION METHODOLOGY:

Vessel Embolised –

Volume of Embolus – **Material used - Gelfoam**

Time Taken –

Complications –

Post Embolisation Angiography Findings –

MASTER CHART

PT ID	NAME	AGE	SEX	CT AND ANGIO INTERVAL (DAYS)	HEMOPTYSIS IN 3 DAYS (ML)	TB HISTORY	EMBOLIZATION	NO. OF RT BRONCHIAL ARTERIES IN ANGIO	ANGIO NBS RIGHT	NO. OF LT BRONCHIAL ARTERIES IN ANGIO	ANGIO NBS LEFT	SIDE OF MAJOR DISEASE PROCESS IN CORONAL MIP SLAB	MAX PL THICK RIGHT MM	MAX PL THICK LEFT MM
1	NILAVALAGI	40	F	1	300	YES	YES	1	YES	0	NO	RIGHT	12.8	0
2	NETHAJI	38	M	2	600	YES	YES	1	NO	0	NO	BILATERAL	7.7	0
3	MANI	60	M	6	100	NO	NO	0	NO	0	NO	LEFT	0	6
4	CHAKRAVARTHY	52	M	2	200	YES	YES	1	NO	0	NO	RIGHT	10.3	0
5	RAJESWARI	55	F	4	120	YES	YES	1	NO	1	YES	BILATERAL	0	4.3
6	RAJENDRAN	18	M	5	50	NO	NO	0	NO	0	NO	BILATERAL	0	0
7	GUNASEKARAN	22	M	2	150	YES	YES	2	NO	2	NO	LEFT	0	0
8	RAMESH	27	M	1	90	YES	YES	0	NO	1	YES	LEFT	0	5.7
9	GOVINDAN	63	M	1	400	YES	YES	1	YES	0	NO	BILATERAL	5.2	2.3
10	RAMESH	33	M	3	500	YES	YES	1	NO	1	NO	BILATERAL	3.8	6.7
11	VENKATRAMAN	23	M	4	15	YES	YES	0	NO	2	YES	LEFT	0	5.9
12	SALAVUDDIN	33	M	3	150	YES	YES	1	YES	0	NO	RIGHT	3	0
13	NAGARAJ	38	M	1	100	YES	YES	0	NO	1	YES	BILATERAL	2.4	6.4
14	NATESAN	50	M	3	150	YES	YES	0	NO	1	NO	LEFT	2	7

PT ID	TOTAL NO. OF RT BRONCHIAL ARTERY IN MDCT	ORIGIN OF RIGHT BRONCHIAL ARTERY	OSTIA OF RT BRONCHIAL ARTERY	OSTIA OF COMMON TRUNK	DIA OF RIGHT BRONCHIAL ARTERY	NO. OF RIGHT NBS	TOTAL NO. OF LT BRONCHIAL ARTERY IN MDCT	ORIGIN OF LEFT BRONCHIAL ARTERY	OSTIA OF LEFT BRONCHIAL	DIA OF LEFT BRONCHIAL ARTERY	NO. OF LEFT NBS
1	3	D4/D5/D5	9 AND 9	12	2.0MM/2.7MM/ 1.2MM	2	1	D5	12	1.3MM	0
2	2	D5/D6	9	12	1.6MM / 0.7MM	0	2	D6/D7	12 AND 12	0.7MM/0.9MM	0
3	1	D5	9	0	1.1MM	0	2	D4/D5	12 AND 12	1.1MM/0.9MM	0
4	1	D5	9	0	4.8MM	1	2	D5/D6	11 AND 12	1.8MM/0.8MM	0
5	1	D5	9	0	1.8MM	0	2	D5/D5	11 AND 12	1.5MM/1.1MM	1
6	1	D7	0	12	1.4MM	0	2	D5/D7	11 AND 12	1.5MM/1.6MM	0
7	1	D5	0	9	2.1MM	0	2	D5/D5	9AND9	0.9MM/1.8MM	0
8	1	D6	9	0	0.7MM	0	1	D5	11	2.9MM	2
9	2	D5/D6	9	12	1.2MM/1.3MM	1	2	D6/D6	12 AND 1	1.9MM/1.1MM	0
10	1	D6	9	0	2.3MM	0	1	D6	12	2.2MM	1
11	1	D5	9	0	1MM	0	2	D7/D7	1AND 12	2.3MM/1.2MM	4
12	1	D6	9	0	2.2MM	1	1	D6	11	0.8MM	0
13	1	D6	9	0	2.5MM	0	1	D6	1	1.7MM	2
14	1	D6	9	0	1.7MM	0	1	D5	1	2.2MM	1

PT ID	NAME	AGE	SEX	CT AND ANGIO INTERVAL (DAYS)	HEMOPTYSIS IN 3 DAYS (ML)	TB HISTORY	EMBOLIZATION	NO. OF RT BRONCHIAL ARTERIES IN ANGIO	ANGIO NBS RIGHT	NO. OF LT BRONCHIAL ARTERIES IN ANGIO	ANGIO NBS LEFT	SIDE OF MAJOR DISEASE PROCESS IN CORONAL MIP SLAB	MAX PL THICK RIGHT MM	MAX PL THICK LEFT MM
15	SARAVANAN	65	M	4	100	YES	NO	0	NO	0	NO	LEFT	0	6
16	PARTHASARATHY	65	M	3	200	YES	YES	1	NO	1	NO	BILATERAL	4.2	4.1
17	SAKTHIVEL	30	M	3	50	YES	YES	1	NO	1	NO	LEFT	1.5	4.6
18	SANTHAKUMAR	45	M	5	500	YES	YES	1	NO	0	NO	RIGHT	5	0
19	RAJALAKSHMI	38	F	2	10	YES	YES	0		2	NO	LEFT	0	2.4
20	GANGAIAH	40	M	5	150	YES	YES	1	YES	1	NO	BILATERAL	3.7	10.5
21	SURESHKUMAR	23	M	5	1500	YES	YES	2	NO	0	NO	RIGHT	3	0
22	ELUMALAI	45	M	3	1000	YES	YES	1	YES	2	NO	BILATERAL	4.3	7.8
23	ASCIFF	18	M	3	300	NO	YES	1	NO	0	NO	RIGHT	2.1	0
24	THIRUNAVUKKARASU	52	M	4	450	YES	YES	1	NO	0	YES	LEFT	0	11.6
25	PALANI	58	M	2	500	NO	YES	1	NO	0	NO	BILATERAL	2.8	6.9
26	KANNAN	46	M	2	1200	YES	YES	1	YES	0	YES	BILATERAL	15.8	12.9
27	SIMON	28	M	1	900	YES	YES	1	YES	0	NO	RIGHT	2.1	4.3
28	KANNAN	22	M	3	300	NO	YES	0	NO	1	YES	LEFT	0	0

PT ID	TOTAL NO. OF RT BRONCHIAL ARTERY IN MDCT	ORIGIN OF RIGHT BRONCHIAL ARTERY	OSTIA OF RT BRONCHIAL ARTERY	OSTIA OF COMMON TRUNK	DIA OF RIGHT BRONCHIAL ARTERY	NO. OF RIGHT NBS	TOTAL NO. OF LT BRONCHIAL ARTERY IN MDCT	ORIGIN OF LEFT BRONCHIAL ARTERY	OSTIA OF LEFT BRONCHIAL	DIA OF LEFT BRONCHIAL ARTERY	NO. OF LEFT NBS
15	1	D5	9	0	1.3MM	0	2	D6/D5	11 AND 12	0.8MM/1.5MM	5
16	2	D6/D5	9	9	1.5MM / 2.1MM	0	1	D5	9	1.4MM	0
17	3	D5/D5/D6	10	12 AN 1	1MM/1MM/1.1 MM	0	2	D5/D6	12 AND 1	1.9MM / 1.9MM	4
18	1	D5	9	0	1.7MM	1	1	D6	12	1.0MM	0
19	1	D6	9	0	0.9MM	0	2	D5/D6	9AND1	1.5MM/1.3MM	0
20	1	D5	9	0	1.8MM	1	2	D5/D5	10AND1	1.6MM/1.1MM	4
21	2	D7/D6	9	12	1.4MM/1.3MM	3	1	D6	12	0.9MM	0
22	1	D5	0	12	2.0MM	5	2	D5/D6	12 AND 1	1.6MM / 1. 3 MM	6
23	3	D5/D6/D5	9 AND 1	1	1.6MM / 1.5MM/ 1.4MM	1	1	D5	12	1.1MM	0
24	3	D5/D5/D6	9	11 AND 12	1.3MM/0.8MM/ 0.8MM	0	2	D5 /D6	11 AND 12	1.3MM / 1.5MM	5
25	2	D5/D5	9	11	3.9MM / 1.2MM	2	2	D5/D6	11 AND 11	3.4MM / 1.0MM	2
26	1	D5	9	0	2.4MM	2	2	D4 /D6	12 AND 1	1.7MM/1.4MM	3
27	2	D5/D5	9 AND 10	0	3.1MM/ 0.9MM	3	2	D6/D6	12 AND 1	1.1MM/1.0MM	0
28	2	D4/D5	9	9	1.4MM/ 0.6MM	0	2	D4/D6	9 AND 2	1.3MM/1.6MM	1

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